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Conference Proceedings

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DECREASING THE RETURN TEMPERATURE IN DISTRICT HEATING NETWORKS THANKS TO A SWITCH TO ALTERNATIVE SUBSTATION ARCHITECTURES

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SUMMARY

District heating networks (DHN) are key systems for managing heating and reducing carbon emissions at a large scale. Therefore, increasing their efficiency is a key to reduce climate change. DHNs with centralized production are supplying hot water to building substations for domestic hot water (DHW) production and space heating (SH) using heat exchangers. Colder water is returned to the centralized district heating system by the return pipe. One of the crucial factors to improve the efficiency of DHNs is to decrease the return temperature in the network to keep the same amount of energy transferred to the buildings while reducing the thermal losses and the flow rate, leading to more savings(Gustafsson, Delsing, and Van Deventer 2010). In this paper, we model and simulate two of the most common DHN substation architectures (interface between the DHN and the buildings) used in a typical third-generation DHN (3GDHC (Lund et al. 2014)), to identify their flaws and propose new district heating substation architectures that can increase the DHN efficiency.

Key-words: District heating networks, Substation architectures, Return temperature, Pre-heating, Efficiency

MODELING

In this section, we will go through the hypotheses underlying our modelling approach. The DHN and heating temperatures are determined by control curves. Several levels of temperature and heating demand were used for the space heating, in order to represent the variety of buildings (new/refurbished buildings and old buildings). We have also incorporated an hourly simulation of DHW usage into our model to reflect the real-world consumption patterns. The design of heat exchangers in our model is based on the pinch method, with a pinch point of 2°C. The values used for the parameterization of the subcomponents of the substation were discussed and validated with DHN practitioners and field operators from different operated assets at ENGIE.
The key performance indicator observed in our simulations is the average return temperature from the substation weighted by the mass flow. Other criteria will be discussed in the section concerning the limits of the model.
The models were developed with the language Modelica and the Buildings(Wetter et al. 2014) Library to simulate and analyse the heat transfer in district heating network substations. First, two classical architectures were modelled: series (one main heat exchanger for both needs, followed by a second heat exchanger for domestic hot water) and parallel (an heat exchanger for the space heating and one for the domestic hot water), as depicted in Figure 1 in the appendix. These traditional architectures have been widely used but present certain limitations in terms of optimizing the return temperature of the network.
To address these limitations, we propose several innovative architectures for the substations:

- Some of the proposed architectures incorporate a pre-heating heat exchanger.
- Some proposed architectures involve a “cascade effect”, which is the partial or full utilization of the outlet water from the water heating systems exchanger to the pre-heating exchanger and/or the space heating.

One of the proposed architectures is depicted in Figure 2 in the appendix.

RESULTS

The main result from our study is the consistent reduction in the average return temperature across all scenarios when implementing our proposed architectures. The reduction ranged between 3.8 and 12.3 °C.
We also found that the lower the heating temperature, the greater the reduction. This is particularly beneficial as buildings are increasingly equipped with low-temperature heating systems, especially new constructions.
Moreover, these architectures showed optimal efficiency with new buildings that have a high water heating demand compared to heating demand. This is due to the higher impact of cold water preheating.
In conclusion, our proposed architectures appear promising for current and future district heating networks, despite some limits (as pressure drops, control difficulties, time resolution of DHW demand, problems of scaling, economic considerations that have to be considered and will be discussed in the full conference paper), and their efficiency will only increase with the renovation of buildings and the spread of low-temperature heating systems.
Additional research has been conducted, focusing on varying storage sizes and an architecture without pre-heating heat exchanger. The outcomes have consistently exhibited similar trends: the proposed new architectures are reducing the return temperature in every case.

CONCLUSION

In conclusion, this paper has proposed a new architecture for DHN substations that holds significant potential for enhancing the efficiency of DHNs. The new architectures has been shown to reduce the return temperature of the DHN across all studied building configurations compared to classical configurations. This reduction in return temperature directly contributes to an increase in the overall efficiency of the DHN, thereby aligning with global efforts to optimize energy use and reduce carbon emissions.
However, while these initial results are promising, further studies are necessary to fully understand the implications of these new architectures. Future research should focus on analysing other factors impacted by the new architectures, such as economic considerations and pressure drops. These additional studies will provide a more comprehensive understanding of the benefits and potential challenges associated with implementing these new substation architectures.
Moreover, experimental studies will be conducted as part of future work to validate and refine the findings of this paper. These studies will provide practical insights into the real-world performance of the proposed architectures and help identify areas for further optimization.

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CONFERENCE TOPIC

Future District Heating and Cooling Technologies - Solutions for Energy Efficiency - Sustainable Renovation

APPENDIX

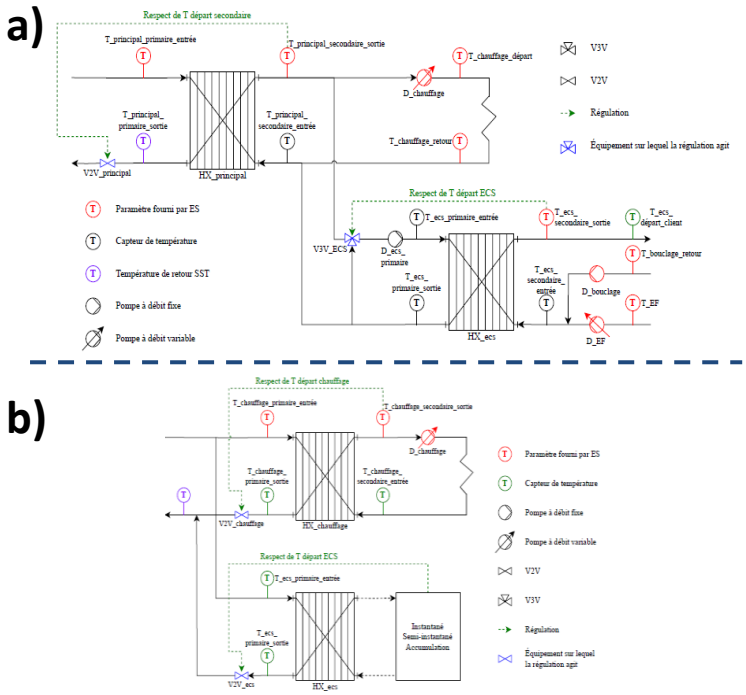

Fig. 1: Two classical substations architectures modelled (in serie (a) and in parallel (b))

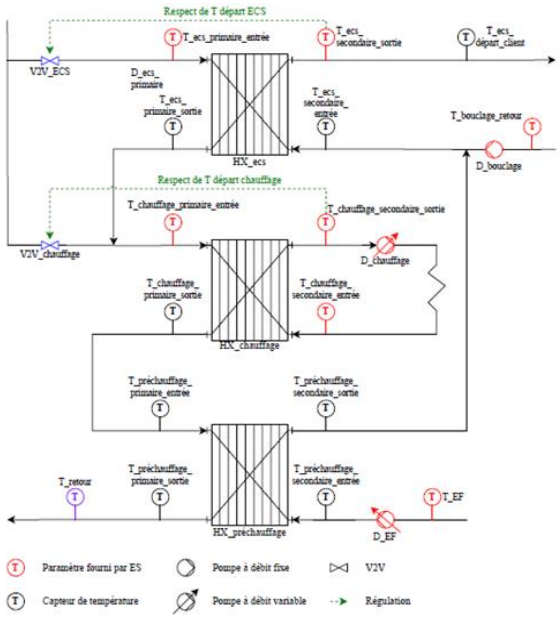

Fig. 2: One the proposed architectures with a preheating exchanger

ISEC 3rd INTERNATIONAL SUSTAINABLE ENERGY CONFERENCE 2024
10 – 11 April 2024
Messecongress Graz
Austria

DEVELOPING HIGH-EFFICIENT BIOMASS-BASED DISTRICT HEATING SYSTEMS FOR RENEWABLE HEAT SUPPLY

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SUMMARY

The transformation of existing biomass-based district heating systems into high-efficient systems requires holistic retrofitting and modernization concepts as well as a portfolio expansion. Within BM Retrofit, the corresponding technological and non-technical measures as well as the system-wide steps, are being developed and tested. The solutions are subsequently implemented and realized in biomass-based district heating networks in Austria at different locations with accompanied data evaluation as well as holistic system validations including life cycle and value chain analysis. Identified optimization potentials and experiences from the whole innovation process will be summarized in guidelines including lessons learned and best practices, that show technical, economic, and ecological benefits and impacts. Moreover, scaling scenarios to generate and assess the market potential and to determine benefits and impacts on the energy system are addressed.
Key words: biomass, district heating, retrofitting, efficiency improvement

INTRODUCTION

Biomass-based district heating systems are crucial for sustainable heat supply in Austria, with approximately 2,400 heating plants and about 150 CHP plants, often with oil and/or natural gas boilers for covering peak load and as a backup [ÖBMV, 2023]. A growing need exists for retrofitting and modernizing these systems to meet future challenges and realise high-efficient biomass-based DH system, both technical and non-technical. Technical improvements include optimizing biomass boilers, integrating storage, enhancing efficiency, and adopting digitalization through sensor technology and control concepts. Non-technical measures involve strategic grid expansion, coupling with energy planning, integrating new energy sources, and considering economic factors like production costs and billing models. Currently, the development of modernization concepts often lacks a systemic and holistic approach. This is addressed in the “BM Retrofit" research project, by creating and demonstrating such an approach for the necessary transformation process. BM Retrofit is part of the Green Energy Lab, a research initiative for sustainable energy solutions and part of the Austrian innovation programme "Vorzeigeregion Energie" of the Climate and Energy Fund.

THE BM RETROFIT APPROACH

Since late 2022, an interdisciplinary team led by AEE INTEC has been working on this three-year project. Their goal is to develop and demonstrate comprehensive modernization concepts for heating networks, focusing on three key objectives: a) adapting existing systems to future requirements, b) contributing to climate targets, and c) enhancing economic benefits and local value creation. The project uses a methodology built on three pillars: technical measures (e.g. flue gas condensation units, heat pump systems, storage technologies, sector coupling), non-technical/organizational measures (e.g. stakeholder analyses and actor integration, new business models), and systemic approaches (e.g. energy management systems to optimise operation strategies, storage management, modelling of DH networks for expansion planning). The "BM retrofit" approach aims to create a sustainable energy system with high efficiency, increased use of locally available renewable energy, maximized

infrastructure synergies, and enhanced resilience, resulting in reduced emissions, resource consumption, and increased supply security and economic efficiency.

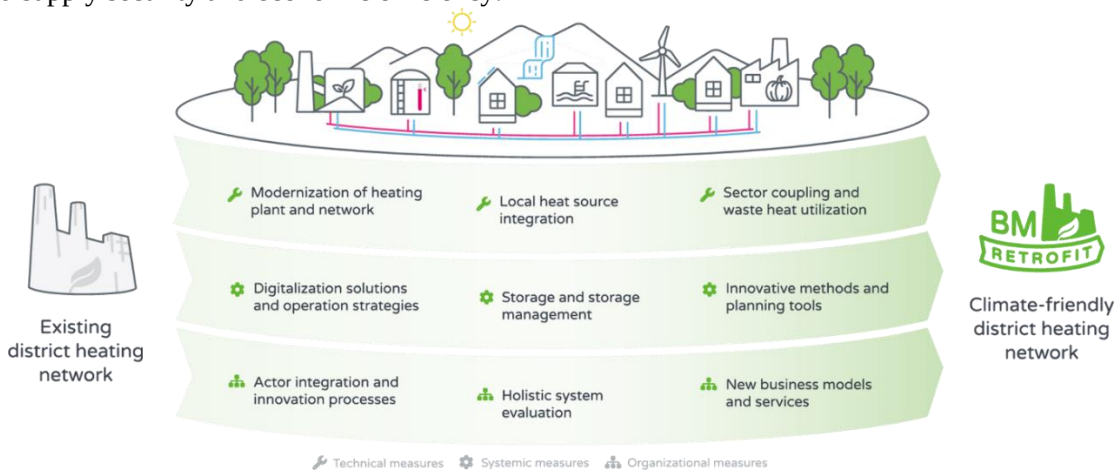

Fig. 1: Methodology for the development of the modernisation concepts, source: Green Energy Lab

ELEMENTS AND SOLUTIONS TESTED IN REAL ENVIRONMENTS

The developed elements and solutions are implemented in different biomass-based district heating networks, so-called demonstrators. These demonstrators are analysed comprehensively, with data evaluation and holistic system validations, including life cycle and value chain assessments. BM Retrofit aims to identify optimization opportunities and compile these findings into a guide of best practices, quantifying technical, economic, and ecological benefits. Furthermore, scaling scenarios for generating and evaluating the market potential and the benefits and impacts for the energy system are identified.

The heating network in Wald im Pinzgau was identified as a suitable demonstrator in the first project phase. A two-stage process is used for the modernisation. In the first phase, summer operation is optimized by incorporating local waste heat and enhancing flexibility. This involves an innovative heat pump concept, tapping waste heat from the cooling cycle of a nearby hydropower plant. A thermal storage tank is introduced for improved flexibility, and the heat pump is powered by on-site renewable electricity. The second phase includes measures for optimizing biomass boiler operation and an intelligent energy management system for efficient heating network operation and grid control. This transformation will allow for 100% renewable and local heat sources, substantially reducing the need for fossil oil boilers, resulting in significant annual savings in oil consumption and CO2 emissions.

Another heating network in Kreuzstetten, Lower Austria, serves around 150 heat consumers, including a drying plant for agricultural products. For the development and evaluation of relevant modernisation measures, corresponding evaluations and assessments of the actual situation as well as a thermal-hydraulic network simulation were carried out on the basis of the available operating data. From this, an optimised control integration of the drying plant as well as a survey of its waste heat potential and an expansion of the storage capacities were derived as possible initial measures. In addition, targeted network expansion and densification potentials are to be investigated with the support of spatial energy planning. Thus, further potentials for increasing the heat supply with renewable energy and for increasing energy efficiency are being determined.

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CONFERENCE TOPIC

- Primary topic: Future District Heating and Cooling Technologies
- Secondary topic: Renewable heating and cooling, including high temperature applications

PLANNING TOOLS FOR DECENTRALIZED HEAT SUPPLY: MODELING THE EFFECTS OF VOLATILE RENEWABLE ENERGIES ON THERMO-HYDRAULIC OF DISTRICT HEATING NETWORK AND OPERATIONAL OPTIMIZATION

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SUMMARY

Decentralized feed-in is necessary for the transition of district heating networks but it comes with various challenges. Software tools for modelling, simulation and optimization allow for a theoretical examination of those challenges and possible solutions. Software tools and use cases from an exemplary research project (called ZellFlex) are presented in this paper. One selected examination – flexibility of supply temperatures by varying setpoint temperatures for a decentral solar thermal system – will be described in more detail.

INTRODUCTION

Heat networks are among the key elements in the penetration of the heat market with renewable energy supply. A significant challenge lies in the restructuring of existing, unidirectional heat supply strategies in the network. It is important to align planning and implementation strategies with the fact that partially decentralized heat generators within the district heating network or customers transitioning to prosumers take on supply tasks in various load ranges. Therefore, it is crucial to manage the resulting partial bidirectionality. In recent years, tools for various aspects have been developed and tested in direct collaboration between academia and industry:

- Monitoring-based, time-resolved forecasting of heat demand on the customer side
- Modelling of decentralized generators (e.g., large-scale solar thermal systems with several 10,000 m²)
- Thermo-hydraulic year-round network simulations of complex existing networks (radial and meshed networks) with central and decentralized heat supply
- Modelling of the temperature field in large tank storage systems (up to 50,000 m³) and derivation of a numerically-analytical model for prediction under various charging and discharging strategies
- Design and operational optimization tool, including sector coupling of electricity, heat, and gas.

OVERVIEW OF USE CASES IN RESEARCH PROJECT ZELLFLEX

Multiple of the tools mentioned were used in the research project ZellFlex, to examine flexibility measures in models of two exemplary existing district heating networks theoretically. These include:

- **Pulsating operation** for temporarily switching off cells using decentralized heat storage and smart control (see Figure 1 - left)
- **Demand-driven supply temperature** for temporal flexibility by aligning actual temperatures with design requirements/guaranteed temperatures or customer requirements (see Figure 1 - right)
- **Local heat retention (type 1)** to reduce heat losses from a long supply line to the cell and the demand of electrical energy for decentralized feed-in pumps.
- **Local heat retention (type 2)** to limit the heat supply from the main network to 20 % (to meet funding requirements of a new construction network acc. to BEW – Bundesförderung Effiziente Wärmenetze)
- **Consumer-oriented, local flexibility of the supply temperature** using heat pumps or mixing stations.
- **Generator-oriented, local flexibility of supply temperature** through individual setpoint supply temperatures of decentralized heat generators to increase the share of renewable heat in the network.

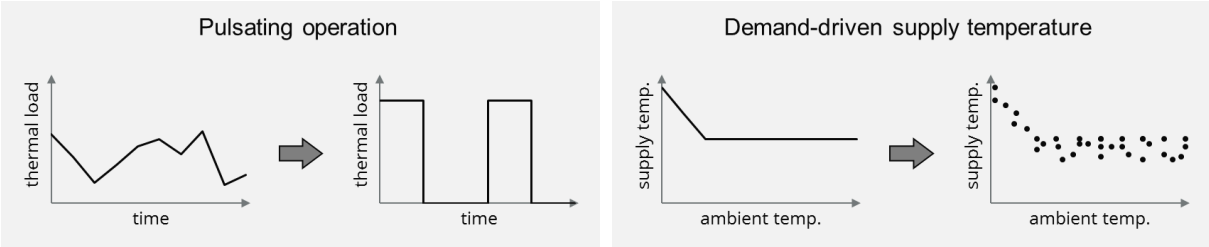

Figure 1: Basic principle of two of the flexibility measures examined in research project ZellFlex

EXEMPLARY USE CASE: INDIVIDUAL SETPOINT SUPPLY TEMPERATURES OF DECENTRALIZED HEAT GENERATORS

One of the flexibility measures in ZellFlex aims at increasing the share of decentralized, renewable heat in the network by allowing them to feed in with a lower supply temperature than the central heat producer. A model of an existing network with a total of 28,5 MW connected load and one central producer was used for this study. Subsequently, a decentralized solar thermal plant was added. In year-round simulations, different scenarios with different setpoints for the solar thermal feed-in temperature were examined. In Figure 2, a solar thermal plant with 500 m² collector area (350 $kW_{peak,th}$) is integrated at the indicated location in the network. The resulting temperature distribution in the supply line is shown for 14th June, 12:00 in the simulated year 2019. In the scenario shown on the left, the solar thermal setpoint temperature equals that of the central heat producer. In the scenario on the right, the setpoint temperature is 10 K lower at every time step. This increases the yearly solar feed-in by about 8 %, but also leads to lower supply temperatures at the consumer locations which might lead to an undersupply. The supply temperatures at exemplary consumers will be evaluated in more detail to estimate possible heat shortages in the full paper.

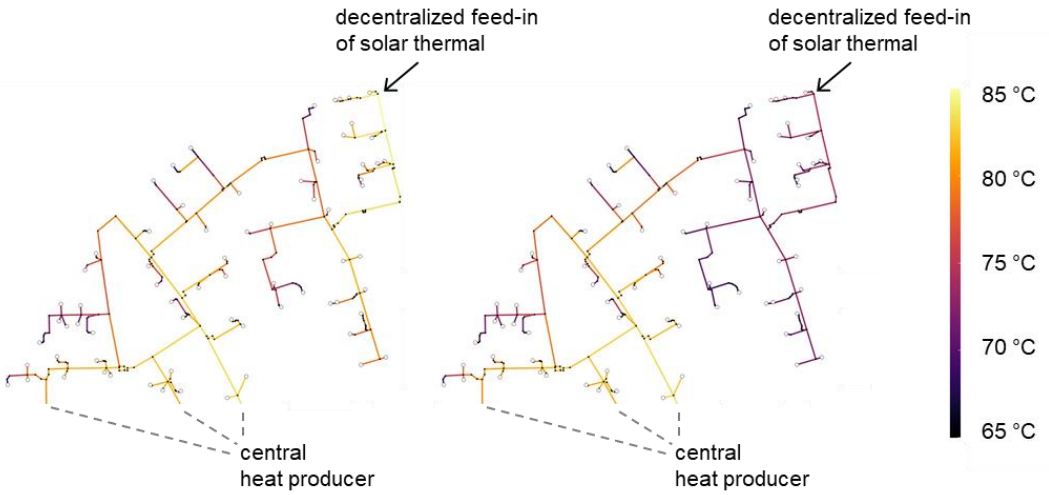

Figure 2: Temperature distribution in a network in reference case with one central heat producer (left) and with an additional solar thermal feeding in with a 10 K lower supply temperature compared to central producer (right).

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CONFERENCE TOPIC

Replacement of big fossil Power Plants by Renewables – Impact on District Heating

ANALYSIS OF DIFFERENT CLIMATE-NEUTRAL HEAT SUPPLY CONCEPTS FOR A DISTRICT HEATING SYSTEM NEAR MUNICH WITH DEEP GEOTHERMAL HEAT AS THE PRIMARY HEAT SOURCE

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SUMMARY

District heating systems are one key element of the transition towards a climate-neutral heat supply since they allow for the use of various renewable heat sources and the increase of renewable heat generation, in particular when combined with seasonal thermal energy storage. Deep geothermal heat is a renewable heat source that can be used to cover the thermal base load of such a district heating system. Also in combination with other renewable heat sources, such as solar thermal or heat pumps, a climate-neutral heat supply for districts or cities can be realised. This paper deals with the analysis of different climate-neutral heat supply concepts that were elaborated for a district heating system currently in planning phase using deep geothermal heat as the primary heat source, located in the town of Graefelfing near Munich, Germany. The authors present, discuss and assess various options regarding renewable heat sources and including (seasonal) thermal energy storage, to fully cover the thermal loads of a new district heating system in a technically, economically and environmentally favourable way.

INTRODUCTION

The town of Graefelfing has around 14,000 inhabitants and is located in the vicinity of Munich in an area that is suitable for the realisation of deep geothermal projects through the technology of extracting heat from underground hydrothermal layers in a depth of around 3 km by means of a so-called doublet system, i.e. with an extraction and an injection well. The municipality of Graefelfing wants to build up a district heating system for parts of the town to use the existing geothermal potential and replace the current heat supply which is essentially based on decentralised boilers fuelled with fossil natural gas.

The Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE) of the University of Stuttgart elaborated and analysed different heat supply concepts for this district heating system using deep geothermal heat as the primary heat source. This means that the concepts mainly differ from each other by the type of auxiliary heat sources used to cover the thermal peak loads and how these auxiliary heat sources are integrated into the overall heat supply concept. The main objective was to compare and evaluate the different concepts from a technical, economic and environmental perspective under the local boundary conditions given.

METHODOLOGY

In a first step, the authors carried out calculations for the determination of the heat demand and developed scenarios for the setup and further extension of the district heating system together with representatives from the municipality. Based on this and the given information about the geothermal potential at the designated geothermal drilling site, a rough estimation of the annual share of geothermal heat of the total heat demand was possible. In a further step, various concepts for covering the thermal peak loads were elaborated. The concepts were first of all analysed from a technical and energetic point of view, i.e. through basic energy balances on a resolution of 15 min, for instance the necessary thermal powers and the resulting annual shares of the different heat sources of covering the total heat demand were calculated. In addition, also dynamic system simulations using the software TRNSYS [1] were carried out to analyse detail aspects. Based on these technical results, the authors carried out

an economic analysis by determining the heat generation costs. In this context, also the current German BEW funding scheme [2] for the setup of new district heating systems was considered. Furthermore, an environmental analysis was carried out by calculating for instance CO_2 equivalent emissions and the use of primary energy.

RESULTS

In this paper, the authors first of all will present the results of the calculated heat demand, the outline of the planned setup and extension of the district heating system and the existing geothermal potential. After this, the elaborated heat supply concepts for the district heating system using deep geothermal heat as the main heat source will be discussed. This comprises the integration of one or several heat pumps using the return flow of the deep geothermal circuit as a heat source, combined heat and power (CHP) plants, solar thermal collectors and the possible conversion of a former gravel pit into a seasonal thermal energy store. The different elaborated heat supply concepts will be explained and the main results of their comparison will be presented by highlighting the most important technical, economic and environmental advantages and disadvantages. As an example, Figure 1 shows how the CO_2 emissions can be drastically reduced with the heat supply concept that was selected as the favourite future one compared to the current way of heat supply using predominantly fossil fuel fired boilers.

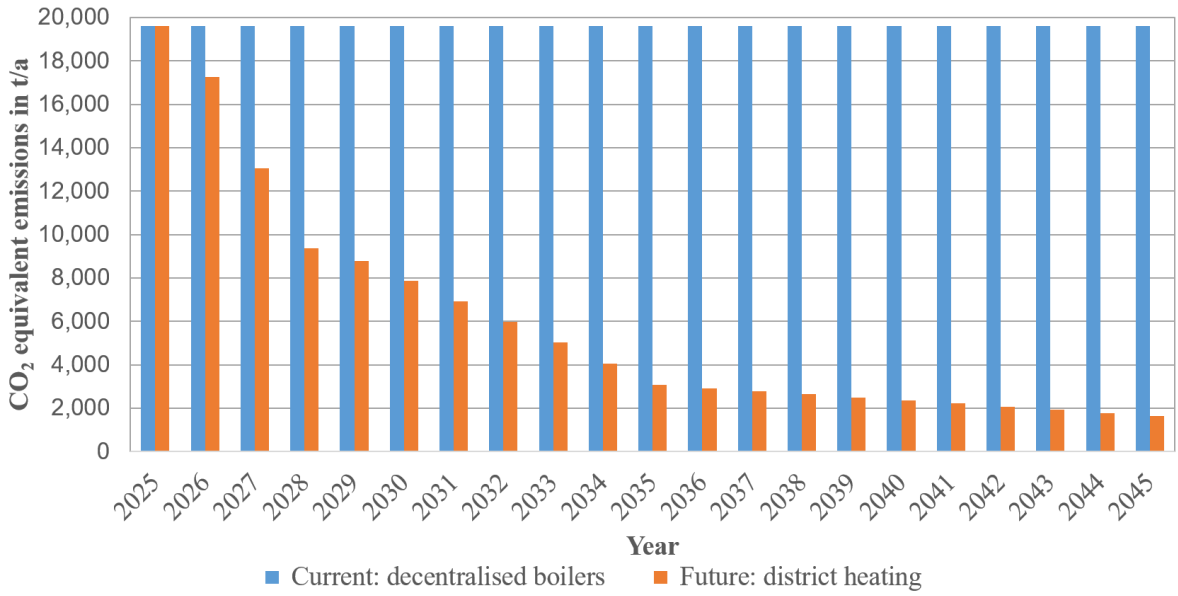

Fig. 1: Comparison between the CO_2 emissions for the current heat supply based on decentralised boilers using natural gas and the selected heat supply concept with a district heating system using deep geothermal heat as the primary heat source

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CONFERENCE TOPIC

Renewable heating and cooling for districts/cities

ANALYSIS OF INDUSTRIAL 5GDHC SYSTEM IN INGOLSTADT AS A STEP TOWARDS CO_2 - NEUTRAL INDUSTRY

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SUMMARY

Bidirectional or shared energy systems are crucial for energy efficiency and decarbonization efforts. Such systems introduce unique planning challenges, inter alia, in the thermal sector where they differ from traditional district heating, thereby requiring novel planning steps. In the context of realized projects, particularly within industrial systems, this topic remains inadequately explored. This study comprehensively examines the technical manifestation and planning process for a shared thermal energy system at an industrial area in Ingolstadt. It encompasses topics such as defining energy requirements and load profiles, assessing potential energy sources and sinks together with innovative components for enhanced system efficiency, and analysing pipe and network dimensions. Through this investigation, the study provides valuable insights and a methodology to facilitate the successful implementation of future industrial 5GDHC systems, furthering the cause of sustainable energy.

Keywords: 5GDHC, planning, design guidelines, district heating, industrial district heating and cooling

INTRODUCTION

The IN-Campus, a newly established industrial park in Ingolstadt, Germany, features a fifth-generation district heating and cooling (5GDHC) network. Compared to a traditional district heating network, this technology allows energy sharing between the connected entities, and balancing heating and cooling demands within the network. This flexibility is achieved by utilizing decentralized heat pumps to adjust temperature levels according to the building demands and operating the grid at lower temperatures. This innovative approach serves as the cornerstone for the envisioned efficient and carbon-neutral operation of the IN-Campus. Related to the novelty of the technology a deficiency of guidelines for planning and operational data can be assessed [1, 2]. Existing research publications often neglect the essential preliminary planning phases and in addition mainly concentrate on small, new urban residential areas [3, 4]. This leads to an absence of comprehensive design guidelines and operational insights, especially in the industrial sector.

This study initiates the journey toward comprehensive design guidelines by conducting an academic review of the IN-Campus energy system and its planning process. The technical system description and the identified guideline aspects presented herein contribute to the scientific community's knowledge base.

DESCRIPTION OF IN-CAMPUS ENERGY SYSTEM

The 5GDHC system in Ingolstadt has been strategically designed to supply a 75-hectare industrial park. Central to its operation, this network encompasses over 9,100 meters of pipelines, featuring a maximum diameter of 800 mm, and holding a total water volume of approximately 2,200 m³. The network combines properties of a heat source and sink, and a thermal energy storage. In terms of additional heat sources and sinks, the system capitalizes on the thermal output of a data center, effectively converting its 2 MW of waste heat into a valuable energy source. Additionally, groundwater wells with a thermal capacity of around 1.5 MW complement the system.

For thermal energy storage firefighting water tanks, equipped with plate heat exchangers are utilized. With a combined volume of 3,150 m³, they possess a substantial energy storage capacity of 130 MWh.

The 5GDHC system is thoughtfully designed to maintain thermal self-sufficiency. For additional security and flexibility, it includes connections to the local traditional district heating and district cooling network.

PLANNING PROCESS OF 5GDHC NETWORKS

In addition to characterizing the 5GDHC network, the planning process for industrial shared energy systems is a key focus of this contribution. Several of the analysed planning steps are outlined below.

Development of energetic requirements and load profiles

A pivotal aspect in designing industrial 5GDHC systems lies in the development of load profiles. Unlike traditional fourth generation district heating (4GDH) systems in 5GDHC the connected entities often operate as so-called prosumers seamlessly transitioning between being producers and consumers – respectively supplying or requiring heat. The process to develop prosumer profiles for industrial areas involved several key steps:

- Defining energy requirements based on legal obligations for non-private entities and projected future needs.
- Introducing two broad building categories (*office building* and *testing facility*), considering characteristic factors like geometry, air exchange rates, occupancy, heating, and cooling loads.
- Combining elements from these categories to derive different prosumer profiles, which were then scaled to create specific profiles for various buildings expected within the IN-Campus.

Analysis of potential source, sinks and storages

In the industrial area energy system, IN-Campus, various sources, and sinks were considered for additional heating and cooling of the network. This included the Danube River, groundwater wells and the data center's waste heat. Each source's temperature profile was assessed, and heating or cooling potential analyzed, respecting network temperature limits (max. 30 °C in summer, min. 5 °C in winter). Other constraints like volume flow and required temperature differences were also considered. The results highlight limitations for the exploitation of the Danube River, making it suboptimal for the analyzed industrial 5GDHC network. Furthermore, additional cooling and heating deficits were assessed within the network that exceeded the capacity of the assessed sources and sinks. The deficits emerged with the phased expansion of the IN-Campus. As a result, various storage technologies, including pit thermal energy storages, were considered in the subsequent planning phases.

Analysis of Pipe dimensioning

The pipe network was sized considering heating and cooling needs, flow rates, and pressure drops to ensure efficient operation. The study illustrated that the incremental expansion of the 5GDHC network requires pump adjustments and modular expansion to meet phase-specific flow and pressure loss needs. Furthermore, an analysis on potential pipe insulation was conducted revealing that additional insulation would be both energetically and economically unfavourable. Similarly, the incorporation of a glycol intermediate circuit was assessed.

Those instances were presented to illustrate the extensive planning process, which will be meticulously and comprehensively examined in the study and organized to enhance its transferability. The results will further be integrated into the ongoing research efforts connected to the IN-Campus and 5GDHC technology.

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CONFERENCE TOPIC

This abstract refers to the Conference Topic “Future District Heating and Cooling Technologies”.

SUSTAINABLE HEAT SUPPLY FOR GREENHOUSES WITH HEAT PUMPS

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SUMMARY

The heating of greenhouses in Germany is responsible for the emission of about 3 million tCO2eq. In the small horticultural city of Straelen in North-west Germany, the possibility to partially replace the heat supply of greenhouses with heat pumps instead of CO2-intensive coal and oil boilers has been investigated. Different scenarios based on the sort of plants and the type of heat pumps have been investigated. In most cases, the levelized cost of heat for the new system (combination of heat pump & gas boiler) was lower than the base case (coal/oil & gas boilers)

INTRODUCTION

In view of the advancing climate change, greenhouses in commercial horticulture offer plants protection against increasing weather extremes and severe weather events. Further ecological and economic advantages result from a higher yield per area, lower water consumption, a reduction in pesticides, and a high recycling potential of water and nutrients. The amount of land taken up for glass greenhouses in Germany increased by around 30% to 4,828 ha between 2010 and 2021 (Bundesministerium für Ernährung und Landwirtschaft, 2023). Globally, a similar trend can be observed. However, heating the greenhouses requires high amounts of energy, which has so far been heavily based on fossil fuels. In 2015, about 2.6 GWh of primary energy was used to heat greenhouses in Germany, of which 28% came from hard coal, 21% from natural gas, and 15% from fuel oil; renewable sources (wood, biogas and plant-based oils) account for about 20% (Bundesministerium für Ernährung und Landwirtschaft, 2021). Estimates put the annual emissions from the heat and electricity demand of commercial greenhouses in Germany at around 3 million tCO2eq.

To date, more than 90% of costs for energy in greenhouses are used for heating systems and similar figures are reported for Netherlands (Kuntosch, 2020). In this context, fluctuating prices for fossil fuels represent an enormous challenge for greenhouse operators in Germany - especially against the backdrop of the recent energy crisis.

One third of all houseplants and flowers in Germany is produced in the small town of Straelen in North-Rhine-Westfalen. For this reason, we focused on this area, and conducted this project together with the local Chamber of Agriculture and their test center. In order to decarbonize the plant industry and reduce future energy costs, the option of replacing a coal or oil boiler as base load heat supply for large greenhouses with a heat pump was analyzed under energetical, economic and ecological aspects.

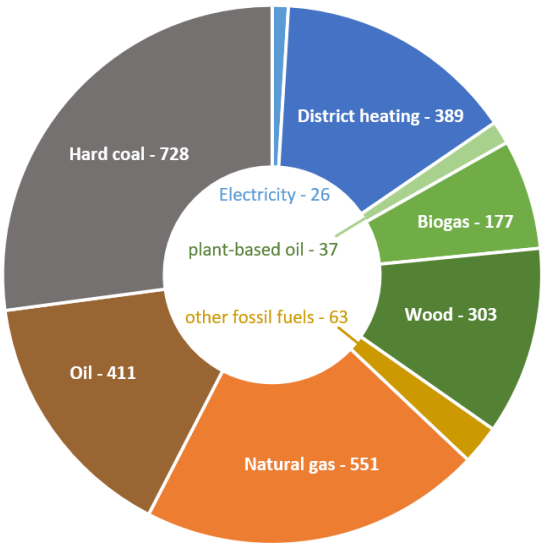

Figure 3: Energy sources used in German greenhouse heating systems in 2015 (in GWh)

METHODOLOGY

To investigate the potential of a heat pump-based system, several scenarios have been simulated using Polysun, a software from Vela Solaris for holistic energy simulations of building or districts.

The reference heating system is a mix of coal and gas boilers, and the tests systems are combining an air/water heat pump or a brine/water heat pump as baseload with a gas boiler for the peaks. Finally, a variant with a wood chip boiler has been investigated since this technology is frequently also considered carbon neutral. The hourly load profiles were calculated with Hortex, a tool operated by the Chamber of Agriculture North-Rhine-Westfalen to calculate yearly load profiles of greenhouses and validated with monitoring data of an actual greenhouse company growing and selling indoor plants. Similarly, the set-temperatures and heating curves have been derived from the monitoring systems of local greenhouses. Most greenhouses are heated using high pipes, either above the cultures and/or to the sides of it. This allows maximizing the light going on to the plants but requires high heating water temperatures to reach the desired climate conditions in the greenhouse. For this reason, and because heat pumps are more efficient at low temperatures, for each scenario we evaluated the energetic and economic benefits of reducing the heating water temperature. This can be done for example with the addition of more pipes, by installing a floor heating or using forced convection.

For each scenario the levelized cost of heat and emissions have been compared. Investment and operating costs were either provided by actual greenhouse operators or derived from literature.

In addition, a sensibility analysis was performed to assess the economical impacts of different electricity and gas price, and of a more performant heat pump.

RESULTS

The economic assessment comparing levelized cost of heat shows that a system combining air/water-heat pump and gas boiler can be on the long-term less expensive than conventional heating based on coal, oil and gas boilers. The high investment costs of a brine-water heat pump, particularly the boreholes, makes it less competitive despite a higher seasonal efficiency. Concerning the CO2-emissions, the investigated heat pump systems are without surprise performing much better than fossil-based systems and allow reductions up to 65% CO2 per year (based on 2021 CO2 emission factors according to the German Environment Agency). But the reduction of CO2-emissions should improve even more in the next years in regard of the decarbonization of the German electricity mix, as projected by the recent environmental laws.

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CONFERENCE TOPICS

- Renewable heating and cooling, including high temperature applications.
- Solutions for Energy Efficiency

MODULARITY TOWARDS SUSTAINABILITY: A NEW APPROACH OF MODULAR HEAT PUMP AND LATENT HEAT STORAGE SYSTEM FOR RESIDENTIAL BUILDINGS

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SUMMARY

Modular heat pump technologies emerge as a promising solution for the phase-out of conventional technologies (e.g. gas-fired boilers) in residential applications. Herein, the modularity stands for a series of refrigeration circuits coupled together to satisfy the overall demand for a wide range of apartments with a perfectly tailored number of refrigeration cycles built up in heat pump (HP) modules. The modular approach allows for keeping the refrigerant charge of R290 per circuit below the critical limit for a safe operation in a residential environment. The work aims to address the optimal hydronic scheme with a control strategy for a set of water-to-water HPs to meet the overall energy demand (i.e. space heating and cooling, domestic hot water). The work considers a conventional heating system with a boiler running on natural gas and a mechanical cooler as a reference system. Results indicate that such a solution outperforms reference systems and achieve annual CO_2 savings up to appx. 2 tons/a for each single apartment compared to its reference counterpart.

INTRODUCTION

The residential heating and cooling sector represents a significant portion of energy consumption in European countries, primarily relying on conventional energy sources like natural gas. This reliance not only strains energy resources but also makes a substantial contribution to climate change through CO_2 emissions. As a result, there is an urgent need to transition away from conventional fuels to reduce emissions and promote the decarbonization of the building sector (Wei, W. and Skye, H. M., 2021). To accelerate this energy transition, scholars identified heat pumps and district heating as crucial components of future energy systems. These technologies play pivotal roles in working towards a sustainable and CO_2-neutral society (Lämmle, M. et al., 2022).

Heat pump technology stands out as an efficient "power-to-heat" solution that leverages low-temperature heat sources (e.g. ambient air, groundwater and geothermal energy) to generate the desired heating supply temperature in buildings using electricity (Maghrabie, H. M. et al., 2023). Moreover, the use of latent heat storage might contribute to the performance of building energy systems due to the high energy density of such technologies compared to hot-water tanks.

In modern residential buildings, standards and regulations define low-temperature thresholds for the hydronic system, which is integral to achieving energy-efficient buildings. Amongst others, floor heating has emerged as a prominent method for delivering space heating, aligning with the goals of energy efficiency and sustainability in building operations (Lämmle, M. et al., 2022). The domestic hot water (DHW) demand, on the other hand, significantly contributes to the total energy consumption. Depending on the preparation system, the temperature level of DHW ranges between 45°C and 65°C. Thus, the required temperature is notably higher than that required for space heating in case of floor heating systems (Emhofer, J. et al., 2020). Therefore, the hydronic system and a proper control strategy must be apparent to satisfy the building demands while maintaining high efficiency.

Accordingly, this work investigates a system of 8 modular heat pumps coupled with a latent heat storage to cover the space heating, space cooling and DHW demands for a building in three climate zones (cold: Helsinki, mild: Strasbourg and hot: Athens). The work further examines several configurations of the hydronic system in order

to provide a guideline for optimal hydronic circuits in such systems as shown in Fig. 1. Additionally, the study analyses the CO_2-emissions reduction from such a system compared to a conventional building energy system.

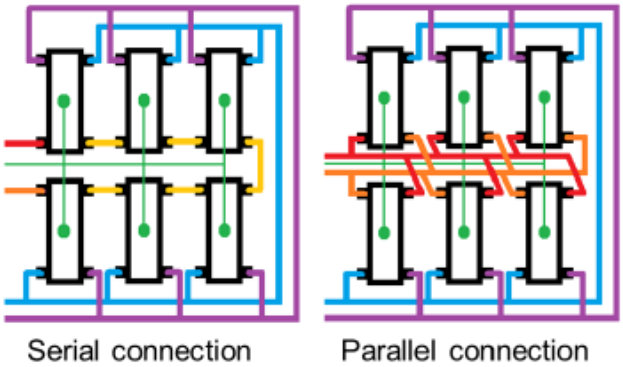

Fig. 1: Table captions (10 pt) should be justified as block and placed below the table

METHODOLOGY

To investigate the applicability of the proposed system and configurations for the modular HPs system, it is crucial to showcase this with the aid of numerical simulations. Thus, a dynamic thermo-hydraulic simulation model is developed in Modelica/Dymola to emulate the HPs integrated within a multi-family house. Furthermore, a realistic DHW consumption profile is used in the investigation. The top-level model comprises of the following sub-system models:

- HP system: A series of HPs each comprises of evaporator, compressor, condenser and expansion valve,
- Detailed building: An intermediate apartment with space heating/space cooling load, DHW demand and heat delivery units (e.g. floor heating, radiators),
- Building distribution system: A hydronic circuit that connects the HPs water side (condenser/evaporator and) together with the circulation pump, latent heat storage, pipes, valves and electrical heating elements, and
- Control system considering all constraints and conditions.

RESULTS

The simulation results showed that for heating operation, during the daylight (and especially in cold climates), the serial configuration outperforms the parallel one since it can reach higher water temperatures; thus the setpoint indoor temperatures are met for a longer time. The parallel configuration, due to the higher mass flow reaching the latent heat storage, is capable to maintain it sufficiently charged over time.

For cooling operation, the results highlighted the possibility of using such heat pumps in a modular approach to satisfy the space cooling demand effectively. In this regard, the coupling of space cooling (via HPs evaporators) and latent heat storage charging (via HPs condensers) with a parallel connection of the hydronic system revealed improved performance compared to its serial counterpart.

Finally, both configurations were compared to a conventional building energy system consisting of a gas boiler and an electric AC unit (present in most households), in terms of CO_2 emissions. Consequently, it is observed this approach represented a substantial reduction in the amount of CO_2 emitted per year with respect to the conventional system, from 1 ton to 2.4 tons of CO_2 per year per studied apartment, depending on the location.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Renewable heating and cooling, including high temperature applications,
- Emerging heat and cold storage,
- Solutions for Energy Efficiency.

ENERGETIC POTENTIAL OF PARALLEL OPERATION OF TWO HEAT SOURCES IN A DUAL-SOURCE HEAT PUMP

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SUMMARY

Dual-source heat pumps can mitigate disadvantages of single source heat pumps: They have fewer geological requirements compared to ground-source heat pumps while having higher efficiencies compared to air-source heat pumps. Parallel operation of two heat sources can also make electric heaters for peak loads obsolete, leading to economic benefits. Parallel operation has not been analysed thoroughly. Four possible interconnections of two heat sources are analysed using a refrigerant cycle simulation, two with similar and two with separate evaporation pressures. The energetic potential of each interconnection is evaluated. It was shown that different heat source temperature levels required separate evaporation pressures to operate optimally. Flexibility in the temperature gradient between the heat sources also required the more complex interconnection of completely split evaporator branches. The energetic benefits still need to be evaluated regarding the economic investment into the system.
Keywords: Dual-source heat pump, parallel operation, energetic potential, refrigerant cycle simulation

INTRODUCTION

Dual-source heat pumps (DSHPs) are a growing focus in current research. A common combination is a ground-source heat exchanger with an air-source heat exchanger. These systems are able to minimize the negative impacts of ground-source heat pumps (usually geological requirements and allowances for borehole heat exchangers and space requirements for shallow ground source heat exchangers) and air-source heat pumps (usually low efficiency during winter and noise emissions). Both limit their usability especially in more densely populated regions, e.g. urban areas [1]. Several researches report a reduction in heat exchanger size of up to 50 % while maintaining comparable annual efficiencies to conventional ground-source heat pumps [2–4]. Similarly, most heat pump capacities are designed to not cover the full peak heating load of the building. Thermal building mass, buffer storages and electric heaters are used to cover these peak heating loads. Especially electric heaters, however, lead to efficiency losses. To prevent the usage of electric heaters, several approaches have investigated options to include parallel operation of two heat sources within a single heat pump to cover the peak load.
Some propositions tried to combine several heat sources on a similar evaporation pressure (e.g. [5, 6]). On similar temperature levels, this allows increased efficiencies and less heat extraction from either heat source. However, detailed analyses are missing on the potential when the temperature gradient between the heat sources is high. Qiu et al. [7] have analysed several combinations of air-source heat pumps combined with a secondary heat source consisting of solar thermal collectors. Here, the solar thermal heat source was always on a higher temperature level, limiting the interconnection requirements by having a strict temperature gradient. Another research developed fully flexible interconnection using air- and ground-source heat exchangers [8]. Here, fully separated evaporator branches (including expansion valve and compressor) allowed parallel operation of both heat sources feeding into the same condenser for heating purposes. However, energetic benefits were only measured at specific ambient conditions and not compared to other interconnections.
The different approaches need to be analysed comprehensively. The energetic benefits and limitations need to be structured and compared. The impacts of temperature gradients, heat exchanger sizes on the heat extractions and efficiency are studied in this research to allow a holistic determination which interconnection should be used for which combination of heat sources.

METHODOLOGY

Four different interconnections of two heat sources (air and ground) were analysed. These included having both heat source heat exchangers 1. on the same pressure level in series, 2. on the same pressure levels in parallel, 3. on different pressure levels in series with an expansion valve in between, 4. on different pressure levels in parallel with two evaporator branches. A refrigerant cycle simulation was built in MATLAB / Simscape and used to evaluate the energetic performance of these four systems. To elaborate on the impact of temperature levels, a medium temperature level was used for the ground-source (5°C) but three air-source temperatures were inserted – one above, one on a similar level and one below the ground-source temperature (15, 5 and -5°C). Generalized heat exchangers, an ideal isentropic compressor based on real mass-flow data and an electronic expansion valve were used. The main comparison parameter was the efficiency and the heating powers. Secondary parameters like overheating temperature and vapor quality were used to evaluate the security of operation.

PRELIMINARY RESULTS

The energetic performance as well as security criteria of operation of all interconnection variants in relation to the different temperature levels will be displayed. A first analysis shows, that interconnections utilizing one single pressure level (variants 1. and 2.) can only benefit from parallel operation when the heat sources are on a similar temperature and therefore evaporation pressure level. Otherwise, the lower temperature heat-source always lowers the total evaporation pressure, influencing the transferred heat ratio from both heat sources and the efficiency negatively. Similarly, variant 3. can only function efficiently if the first heat exchanger in refrigerant flow direction has a higher temperature level: Otherwise, the performance is affected negatively. Only the parallel evaporator branches (variant 4.) allow operation at all temperature variations without limitations. However, the economic costs are by far the highest from all interconnections due to additional costly compressors needed.

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications; Solutions for Energy Efficiency

ANALYSIS OF DIFFERENT HIGH TEMPERATURE HEAT PUMPING-CYCLES FOR INDUSTRIAL APPLICATIONS WHERE DISTRICT HEAT IS USED AS HEAT SOURCE

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SUMMARY

Industry is one of the largest emitters of greenhouse gases worldwide (30%). This is because natural gas has been mostly used for process heat supply so far, even if the required temperature levels are not higher than 150 °C. Within this paper, a suitable application for suppling these industrial plants with district heat by lifting the temperature level up via a high temperature-heat pump (95 to 150 °C) is discussed in detail. From an economic point of view, industrial plants are very interesting end consumers for district heating suppliers, since they have a high and largely constant heat demand throughout the year. However, the required low return temperature of the grid can have a negative impact on the coefficient of performance of the heat pump. In this paper, a comparison of different heat pumping-cycles fitting for this application is performed. Simulation results show that for high heat source temperature spreads, the reverse Joule/Brayton cycle is the most suitable. In addition, a novel rotor design for this cycle using rotational forces and an environmentally friendly refrigerant is presented.

Keywords: Perkins/Evans-, Lorentzen-, Osenbrück- and reverse Joule/Brayton-cycle, load curves, exergy, new rotor design, economic analysis

MOTIVATION

Globally, industry is one of the largest energy consumers (28%, see Gallichon et. al (2017), with 75% of industrial energy demand used for process heat (52% in the low and medium temperature range acc. Philibert (2017)). However, based on that temperature level industry facilities could not be supplied by most district heating grids, as the temperature levels of most grids (of about 95°C supply temperature) are too low. This situation can be improved by the utilization with heat pumps (HP), which leads to an energy efficiency increase in the industrial sector (see e.g.: Zotter & Rieberer (2014) or De Boer et. al (2020)).

APPLICATION

With the utilization of a high-temperature heat pump (HT-HP) for raising the temperature level of district heat (DH), it is possible to supply industry facility with process heat of ca. 150 °C and higher, see Figure 1. However, when using DH as heat source it has to be considered that the return temperature (t_(R,DH)) should not be higher than 60 °C. Increasing t_(R,DH) leads on the one hand to a decrease in the total heat capacity of the entire grid at constant mass flow and supply temperature, on the other hand a higher t_(R,DH) would also have a negative impact on the efficiency of the supply side, see Zotter et. al (2023a). It is therefore essential to consider the external temperature spread of source and sink when designing a HP for this application. Examples of this industrial application include various heating processes such as the provision of hot air, hot water or steam or air preheating for drying processes (e.g.: Wilk et al. (2019)).

ECONOMICS

From an economical point of view industrial plants are very interesting end users for DH-grid operators since they consume a high amount of heat mostly over the entire year (and constant over the entire day) and not only in winter periods. Therefore, industrial plants consume a high constant heat capacity with high operating hours over the entire year. This reduces the ratio between peak and base load, so that the base load increasingly dominates in the annual load curve of the DH-grid. As a result, residual loads in the grid decrease and the full load hours for CO_2-free energy sources such as deep geothermal energy, industrial waste heat, etc. increase. This has a positive impact on the economic profitability of these energy sources, which are characterized by high investment but low operating costs. Above all, the increase in the required heating power in summer favours the integration of renewable sources such as solar energy. Furthermore, the heat demand of a manufacturing plant is much more predictable than comparatively weather-related heat.

SIMULATIONS

According to Arpagaus et. al (2018) there are several different manufactures offering electrical-driven HPs for industrial application. However, different cycles and refrigerants are used for it. This paper shows the results by means of simulations, which cycle - form Perkins/Evans- (Perkins, 1834), Lorentzen- (Lorentzen, 1990), Osenbrück- (Vehovec et al., 2013) and reverse (counter-clockwise) Joule/Brayton-Cycle (Adler et al. (2011) - fits best for the respective application, using different refrigerants, different working pair and different gases. The focus within this simulation study lays on the one hand on the required high target temperatures and temperature lift, and on the other hand on the available and required temperature spreads at heat source and sink and its influence on the coefficient of performance (COP). The analyses shows that high temperature spreads on the source side have a high negative impact on the Perkins/Evans-Cycle and the lowest on the Joule/Brayton (see Figure 5). This is because the temperature glide of the reverse Joule/Brayton-cycle itself fits the best to that application, while a high temperature spread on the source side significantly lowers the low-pressure level of the Perkins/Evans-Cycle. According to Lorenz (1894), using a mean logarithmic source temperature ($\bar{T}_0$, see Eq. 1) and a mean logarithmic sink temperature ($\bar{T}_H$, see Eq. 1), considering inlet and outlet temperatures of it, represents the better heat pump application for sensible heat sources and sinks, while the Carnot cycle fits better for latent heat sources and sinks.

$$\bar{T}_0 = \frac{t_{0,\mathrm{In}} - t_{0,\mathrm{Out}}}{ln\left(\frac{T_{0,\mathrm{In}}}{T_{0,\mathrm{Out}}}\right)}, \qquad \bar{T}_H = \frac{t_{\mathrm{H,out}} - t_{\mathrm{H,IN}}}{ln\left(\frac{T_{\mathrm{H,OUT}}}{T_{\mathrm{H,in}}}\right)} \qquad \text{Eq. (1)}$$

Furthermore, as shown in Figure 5, within this paper, a simple way to determine the coefficient of performance (COP) for all the above-mentioned heat pumping cycles the temperature, enthalpy – diagram is shown, even for the reverse Joule/Brayton cycle by shifting enthalpies.

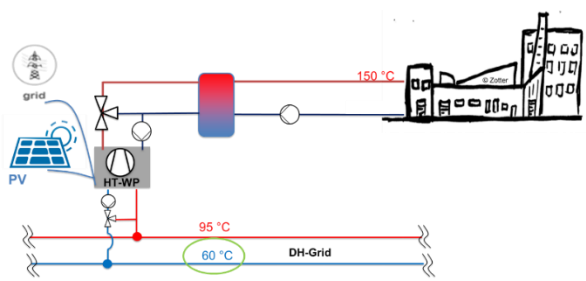

Figure 4: Application: industrial plant supplied by DH-grid using an HT-HP (Source: Zotter et. al (2023b))

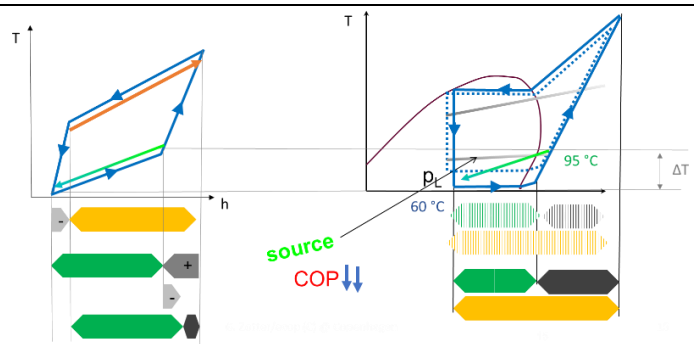

Figure 5: Cycle analysis for high temperature spread at the heat source, comparing counter-clockwise Joule/Brayton-cycle (left) and Perkins/Evans-Cycle (right); black: electricity consumption, orange: heat sink, green: heat source.

CONCLUSION AND OUTLOOK

The application shown in this paper will be core way to extend the DH-grid with new economically attractive end consumers like industrial plants and make a big step towards reducing the gas consumption in industry.

Furthermore, a novel rotor design (Längauer & Adler (2023)) for that cycle using rotational force in the rotational heat pump (RHP) (Adler et al. (2011)) will be shown, which saves space. A further benefit besides the higher COP for this RHP application is that compared to synthetic refrigerant the used gas mixture inside is absolute environmentally friendly, in terms of ODP, GWP and PFAs as well as inflammable and non-toxic.

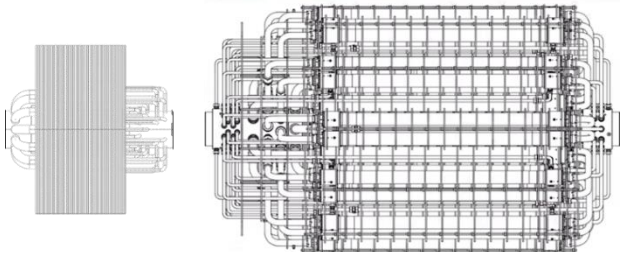

Figure 6: Comparison of rotor designs (same scale for both); left: Integrated- Rotor design based on diffusion bonding, right: assembled rotor-design.

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature application.

MODEL-BASED CONTROL OF ABSORPTION HEAT PUMPING DEVICES – GENERAL APPROACH AND EXEMPLARY APPLICATION TO SOLAR COOLING SYSTEMS

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SUMMARY

Absorption heat pumping devices (AHPDs, comprising heat pumps and chillers) can provide heating and cooling in a resource-efficient manner. However, their perceived complexity has limited their widespread application. This contribution shows how mathematical models, systematically capturing this complexity, can be used for model-based control of AHPDs (on the device-level for model-predictive or state feedback control and on the system-level for optimisation-based energy management systems) to facilitate their integration into energy systems, and discusses an exemplary application to solar cooling systems.

INTRODUCTION

AHPDs can lift low-grade energy to usable temperatures by using thermal energy as driving force, ideally provided by sustainable technologies such as biomass boilers or solar thermal collectors. They can be used in a very versatile way to generate heating and cooling without putting a strain on the power grid. However, AHPDs are a comparably complex technology with many in- and output variables, which often hinders their implementation in real applications. This complexity, however, can be systematically described with mathematical models, which can be used in model-based controllers to facilitate the integration of AHPDs in energy systems. This contribution aims to illustrate how this can be done both at the device level, i.e., to control the AHPD's outlet temperatures or heat flow rates, and at the system level, i.e., to control energy systems containing AHPDs efficiently.

MODEL-BASED DEVICE-LEVEL CONTROL

At the device-level, the control task involves selecting input variables that the controller can manipulate (manipulated variables) to control desired output variables (controlled variables). These input variables include the solution flow rate inside the AHPD and the inlet temperatures and flow rates in the three hydraulic circuits (hot, cooling and chilled water), while the output variables include the corresponding outlet temperatures and heat flow rates. Depending on the specific application, i.e., which heat sinks and sources the AHPD is connected to, different sets of in- and output variables may be chosen as manipulated and controlled variables. Therefore, it is advantageous to employ a control approach that can be systematically adjusted for different applications and is capable of handling multi-input-multi-output (MIMO) systems. Both a state feedback controller and a linear model-predictive controller (MPC) are well-suited control methods for this purpose. To apply these control methods for AHPDs, a linear state-space model of the AHPD, i.e., a model containing only linear differential equations, is necessary. For this, a linearized version of the nonlinear AHPD model from (Staudt et al., 2023a) is used, allowing to systematically capture the dynamic correlations between in- and output variables. Utilizing such model-based MIMO control methods provides an additional advantage, as it allows the use of more

manipulated than controlled variables in a systematic manner, thereby extending the operating range of an AHPD, as shown in (Staudt et al, 2023b).

MODEL-BASED SYSTEM-LEVEL CONTROL

AHPDs are typically integrated into larger energy systems, which are often subject to fluctuating operating conditions. To effectively manage the interaction between the individual devices, a system-level control is necessary, which specifies the set points for the device-level controllers, e.g., of the AHPD, and ensures that heating and/or cooling demands are met, ideally maximizing system efficiency. State-of-the-art solutions employ a system-level control based on expert rules. However, this approach tends to yield suboptimal system efficiency. A more advanced approach is the use of an optimization-based energy management system (EMS), using a mixed-integer linear program formulation, see, e.g., (Moser et al., 2020). This EMS employs simple models of the system's devices, allowing for systematic adjustment to different energy systems. It can also incorporate forecasts for factors such as future energy demand and solar irradiation, and operates the system in such a way that a specifiable cost function is minimized. Currently, such EMS cannot account for the fact that the performance of many devices, including AHPDs, is substantially influenced by the feed temperature level. Therefore, the EMS is extended to consider varying temperature levels, and the nonlinear AHPD model from (Staudt et al., 2023a) is used to derive characteristic curves that depict the temperature-dependent performance of AHPDs to be used in the EMS.

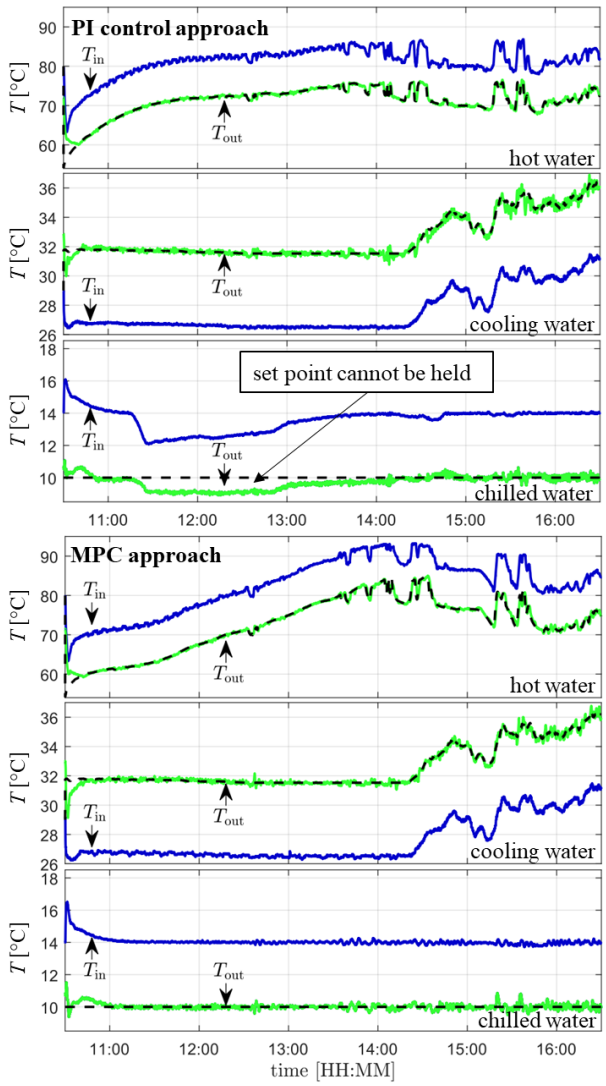

Fig 1: Comparison of PI and MPC control approach for hardware-in-the-loop test run

EXEMPLARY APPLICATION

To underline the practical applicability of model-based control for AHPDs the presented approaches are applied exemplarily to a solar cooling system, consisting of an AHPD, a solar collector, a cooling tower, and a building with cooling demand. Fig 1 shows exemplary results of a hardware-in-the loop test run, showing that an MPC control approach can keep the controlled variables closer to their set points compared to a PI control approach. The final contribution will show the methods and practical results for both device- and system-level control for a solar cooling system.

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CONFERENCE TOPIC

This abstract refers mainly to the following conference topics: Renewable heating and cooling, Smart Services and System Operation, Solutions for Energy Efficiency, Excess Heat Energy and Resource Recovery from Low-grade Sources, Future District Heating and Cooling Technologies.

SURVEY OF INDUSTRIAL EXCESS HEAT POTENTIALS IN AUSTRIA

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SUMMARY

As part of the research and development service for the Energy Transition 2050 program, the technical waste heat potentials for both energy-intensive and energy-extensive Austrian industry were surveyed. The waste heat sources were also classified according to temperature range, heat transfer medium, industrial sector and geographical location. A total technical waste heat potential of around 34 TWh was identified. Companies in the group of energy-intensive industry, which were mainly calculated using the bottom-up method, account for a total waste heat potential of around 26 TWh. Statistical top-down methods were used to identify a waste heat potential of around 4 TWh each for energy-intensive industry and wastewater treatment plants. For geographical localization, the results were integrated into an existing GIS application in order to be able to identify possible heat sinks into local district heating networks.

INTRODUCTION

The final report of the accompanying research, which was carried out as part of the development of the Austrian heating strategy [1], clearly stated that a comprehensive data basis regarding Austrian waste heat potential is lacking and therefore needs to be developed.

This can also be seen when analyzing the surveys available for Austria: The surveys only show sections of the waste heat potentials and heat supply structure in Austria, which are therefore not detailed enough or incomplete as they are obsolete or no longer available (KPC waste heat survey) or only contain local potentials (i.e. Waste Heat Register Styria [2], Heat_re_USE.Vienna [3]). In terms of GIS representation, the Austrian Heat Map (Austrian Heat Map) [4] is a very powerful platform for the heating sector, but it does not provide a comprehensive and detailed representation of waste heat data, as this has not yet been collected completely and in detail. This paper shows how and with which methodology this gap was closed for Austria.

METHODOLOGY

In order to be able to calculate the waste heat of industrial companies, the first step is to determine the energy used, whereby a distinction is made between the bottom-up and top-down approach. The bottom-up approach used here is based on publicly available data such as environmental reports, EMAS environmental declarations or company reports, broken down into the individual energy carrier.

If this information is not available, CO2 emissions from the European Union database [5] are used and the energy input is recalculated via the energy carrier. For industries with process-related CO2 (e.g. steel industry, cement production), this must be taken into account appropriately. Exothermic and endothermic processes must also be taken into consideration accordingly. Once the energy input is known, the next step is to research the processes and reproduce them as accurately as possible. This enables waste heat flows to be determined via flue gas, condensation, waste water or products.

With top-down approaches, key figures are formed from statistical data (e.g. energy per employee), and then used to determine the energy demand of the companies. Key figures from the literature or from our own calculations of similar industrial sectors are used to determine waste heat. A combination of bottom-up and top-down calculations is also possible.

The results always represent the technical potential and do not take into account economic feasibility or the possibility of immediate use. Due to the significant amounts of waste heat in the lower temperature range, but also to take account of low-temperature and anergy networks, the following temperature classes were selected: >100 °C, 50 to 100 °C, 0 to 50 °C.

RESULTS

A total technical waste heat potential of around 34 TWh was identified for all sectors evaluated, including gas compressor stations and wastewater treatment plants (Fig. 1). Around 300 companies in the energy-intensive industry, which were mainly calculated using the bottom-up approach, account for a total waste heat potential of around 26 TWh. Using the statistical top-down method, a total waste heat potential of around 4 TWh was identified for over 1500 companies in the energy-intensive industry with more than 50 employees.

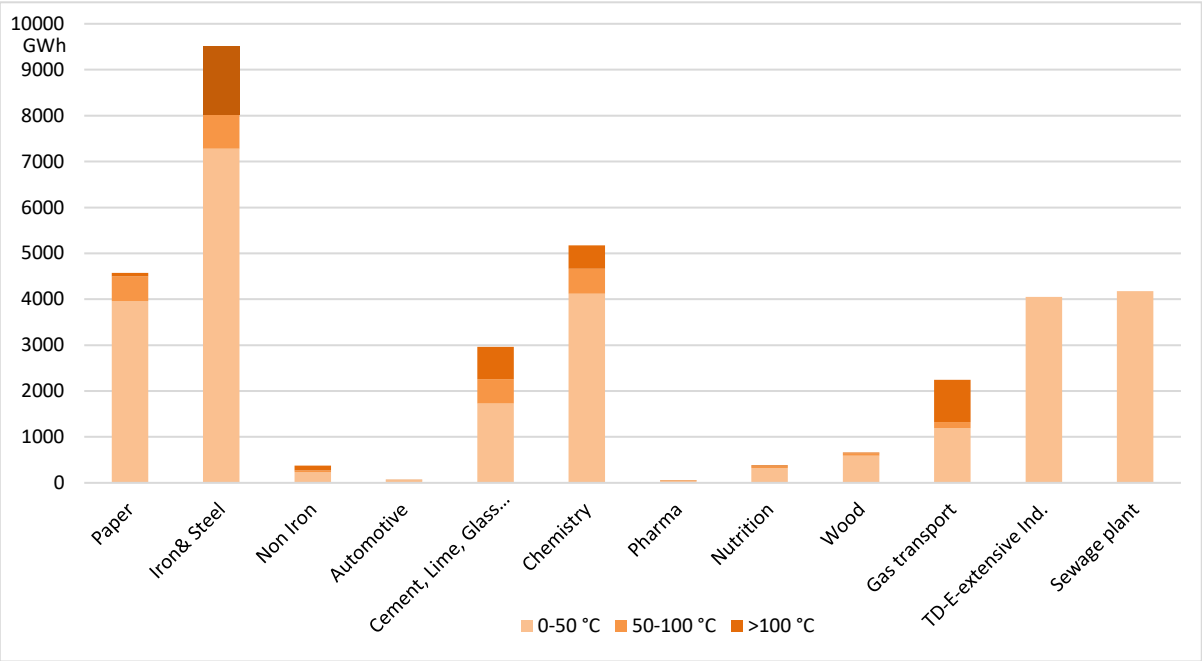

Fig. 1: Results of the waste heat survey by various ÖNACE categories and temperature ranges

In addition, the waste heat potential of over 600 wastewater treatment plants was estimated at around 4 TWh.

It is clear to see that waste heat in the lower temperature range up to 50 °C accounts for by far the largest share, at almost 28 TWh.

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CONFERENCE TOPIC

Excess Heat Energy and Resource Recovery from Low-grade Sources

RENEWABLE GASFIELD – LESSONS LEARNED FROM COMMISSIONING TOWARDS STABLE OPERATION

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SUMMARY

Two years ago, the concept of the Renewable Gasfield Gabersdorf was introduced during the ISEC 2022 conference. Now, two years later we are able to present our "real-life" experience which we made in the meantime, covering the authority engineering process, the construction period and – most important – the start-up and commissioning process.
In this period not only the P2G-plant was set into operation, but we also saw an increasing number of hours with a surplus of solar electric power produced in the surrounding countryside. So, at several hours throughout the year the electric power output of the already existing solar parks had to be reduced in order to maintain a stable electric grid.
Although the PEM-electrolyser with 1.4 MW total electric power uptake is still to be considered as a small-scale project I becomes obvious that the concept of producing green hydrogen and then using this hydrogen to upgrade raw biogas to pure biomethane will be a perfect concept to store a surplus in electric power permanently in the existing natural gas grid.

INTRODUCTION

In the Styrian research project "Renewable Gasfield" a power-to-gas (P2G) plant was built in Gabersdorf near Leibnitz. It shows the role of renewable hydrogen and biomethane as important core components in a future energy model region considering sector coupling.
Green hydrogen is produced by a 1.4 MW_{tot} PEM electrolysis with a production capacity of 210 Nm³ H_2/h or 140 tons/a. The energy is provided mainly through certified green electricity (mainly wind power) from the grid but also by on-site photovoltaic modules (750 kWp). The produced green H_2 is stored at 30 and 500 bar and can be filled into distribution trailers in order to be transported to nearby industrial sites or research facilities.
For the methanation, biogas is delivered from the nearby agricultural biogas plant. Roughly 260 ha of agricultural land is used to renewably grow the processed crops for the generation of 260 Nm³/h biogas. The biogas contains around 52 v% CH_4 and 46 v% CO_2, is converted into 500 kW electric power and also roughly 550 kW thermal power in a CHP unit. The thermal power is used in a local heating network.
21 Nm³/h of the biogas is withdrawn and transported to the new P2G plant. After dehumidification and cleaning with activated carbon, biogas is introduced into a catalytic reactor together with 40 Nm³/h hydrogen from the electrolysis for direct methanation. The catalytic reaction takes place on a specialized catalysator at medium temperature and pressure levels. The produced biomethane (21 Nm³/h) with a remaining share of hydrogen (< 10 v%) fulfils the requirements of the Austrian gas network (ÖVGW GB 210-2021) and is injected into the local natural gas grid.

TIMELINE

Looking back at the timeline we see a quick and straight forward authority engineering process which lasted from March 2021 until April 2022. The construction on site started in April 2022 and was completed after only six months already in September 2022. Start-up followed and the commissioning was completed in March 2023.

Fig. 1: bird-view of the P2G-site

Parallel to the construction phase a HAZOP-study on the intersections of the individual parts of the plant was undertaken. In the HAZOP process engineers from all involved contractors were involved. The HAZOP study was necessary to supplement the suppliers' CE markings, but the issuing of a declaration of conformity by the system operator turned out to be not necessary.

RESULTS AND DISCUSSION

Based on the experience of the start-up process of all components proofed their promised efficiency. This and the overall efficiency will be reported in detail in the full-paper and during the conference. Due to the nature of this innovative full-scale renewable energy research project several problems arose and had to be solved.
The commissioning process involved several players, among them notified bodies and public authorities. All these stake-holders must be managed in time and well-coordinated in order to complete such a plant in time. Even small inaccuracies, such as a lack of confirmation of conformity of a minor unit, can significantly delay the acceptance process and thus the commissioning of the entire system. Likewise, unexpected defects in simple seals can lead to an undesirable chain of errors if no reliable problem detection measures are implemented.
On the other hand, this combination of green hydrogen with a biogas production plant has the urgently needed potential for storing volatile green electricity and – at the same time – grid stabilization, all while maintaining an acceptable overall energy efficiency.

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CONFERENCE TOPIC

Coupling of Energy Sectors, Flexibility and Stability of Thermal and Electric Grids

COMPARATIVE ANALYSIS OF SOLAR TOWER AND PARABOLIC TROUGH COLLECTORS FOR SOLAR HEAT IN STEEL INDUSTRY: A CASE STUDY

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SUMMARY

Concentrated Solar Thermal (CST) systems emerge as a promising alternative to replace fossil fuels used in industrial thermal processes due to their high energy density and dispatchability. In this study, a comparative analysis of two CST systems, Solar Tower (ST) and Parabolic Trough Collector (PTC), has been made to replace natural gas used in the steam generation process in Turkiye's largest steel production plant, located in the Mediterranean Region of Turkiye (36°44'41.71"N, 36°13'23.46"E). Both the ST and PTC systems were placed in a field area of approximately 0.4 km^2. The results have shown that the PTC system could meet the plant's energy requirements for two-thirds of the year, while the ST system could meet the plant's energy requirements for one-third of the year. This could reduce CO_2 by about 12.7 kilo-tones for the ST system and 19.1 kilo-tones for the PTC system.

Keywords: Concentrated Solar Thermal (CST), Parabolic Trough Collector, Solar Heat for Industrial Processes (SHIP), Solar Tower

INTRODUCTION

After the withdrawal of the Paris Agreement in 2016, Turkiye aims to achieve net zero emission status by 2053 (Demir, 2022). In this regard, Turkiye has enormous solar energy resources. CST systems convert sunlight into heat at medium and high temperatures and are utilized in industrial operations, such as process heat, steam generation, and chemical reactions (Nathan et al., 2023). This study examines the applicability of two CST systems, PTC and ST, in industrial processes, highlighting their benefits and drawbacks.

METHODOLOGY

Two of the most important climatic conditions affecting thermal performance are solar irradiation and wind speed (Asif et al., 2017). Figure 1 shows these parameters used in the simulations and performance calculations in this study. The optimized layouts for ST and PTC are given in Figures 2 and 3, respectively. The considered heat transfer fluids (HTF) are binary molten salt for ST and Slytherm 800 for PTC. Mirrors have reflectances of 91% and 94% obtained for commercially available systems for ST and PTC, respectively. Heliostat geometry for ST

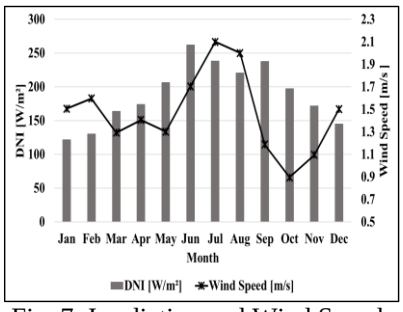

Fig. 7: Irradiation and Wind Speed Data used in the Simulations

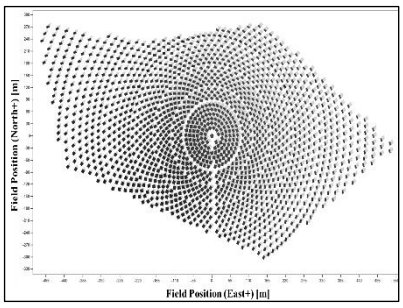

Fig. 8: Heliostat Field for the ST of the Installation Area

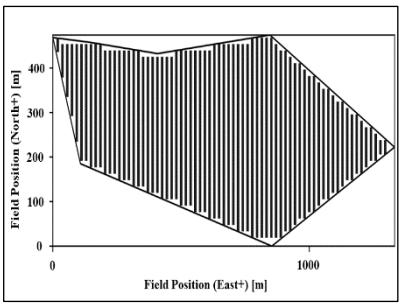

Fig. 9: Layout of Parabolic Trough Collectors

is a square with a side length of 8 m, and the PTC type is SkyTrough with an aperture area of 83.4 m^2. The heliostat field contains nearly 2560 heliostats, with a solar tower of 110 m high. The industrial process requires a thermal energy demand of about 7.9 GWh/month corresponding to the generation of steam of 100 kilo-tones at a temperature of 440ºC and a pressure of 40 bar.

RESULTS AND DISCUSSION

The simulation results show that the PTC system produces 112 GWh of useful thermal energy, while the ST system produces 76 GWh, as shown in Figure 4. The marginal difference in the results is increasing in summer due to higher wind speeds in these months, as shown in Figure 1. This is because ST systems experience receiver convective losses more since it has more exposure area, and the PTC receiver has a vacuumed layer on top of it. Consistent with the solar irradiation data, the highest generation is found as 15.4 and 9.6 GWh for PTC and ST, respectively, in June, whereas the lowest production is estimated as 4.15 and 3.37 GWh for PTC and ST, respectively, in January. Annually, PTC and ST systems meet 118% and 80% of the total thermal energy demand of the process in the steel factory of interest, considering the same land area.

In addition to comparing ST and PTC technologies for the same installation area to satisfy industrial demand in terms of thermal performance, this study will include financial aspects of the comparative analysis of these technologies in terms of Levelized Cost of Heat (LCOH).

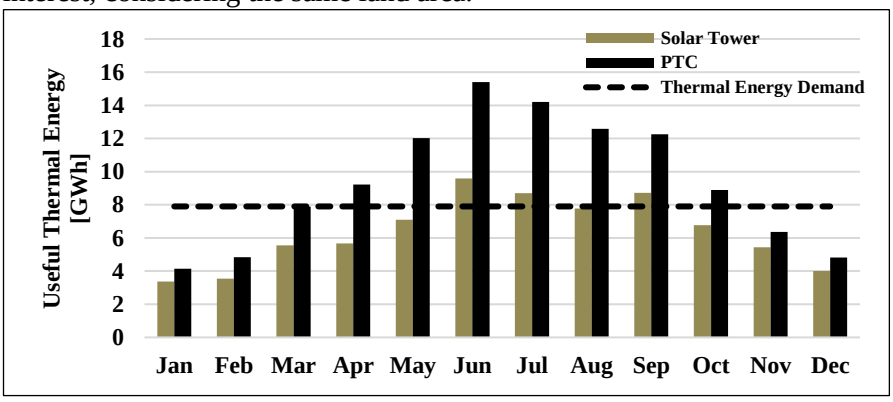

Fig. 10: Useful Thermal Energy for ST and PTC Compared with Energy Demand

CONCLUSIONS

The ST and PTC systems were both installed in a 0.4 km^2 field. The results revealed that the PTC system could fulfil the steel production plant's energy demands for steam generation, which is about 7.9 GWh throughout the year, for two-thirds of the year, while the ST system could supply them for one-third of the year. This could reduce CO_2 by about 12.7 kilo-tones for ST system and 19.1 kilo-tones for PTC system. Given that the process heat is considered an intermediate good and the company provides the land area for installation, ST and PTC installations are viable options for mitigating the use of natural gas in the industry, except for the high capital costs. Consequently, this study serves as a foundation for incorporating CST systems into steel industry facilities that can be applied in different global regions.

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CONFERENCE TOPIC

This abstract refers to Renewable heating and cooling, including high temperature.

IT-FRAMEWORK FOR DIGITAL ENERGY TWIN/SHADOW APPLICATIONS

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CONFERENCE TOPIC

Digitalization for Future Energy Systems. Solutions for Energy Efficiency.

SUMMARY

Digital Energy Twins are IT systems, interconnecting sensor data, simulation models and user interfaces to formulate a virtual representation of the behaviour of real energy systems. Digital Energy Twins are useful to predict the behaviour of energy systems under varying boundary conditions and to optimize their operation considering economic and ecologic impact. Within the project "Digital Energy Twin" (funded by the framework of Austrian Climate and Energy Fund Programme Energy Research e!MISSION under FFG project no. 873599) two different concepts of Digital Twins applicable to industrial energy systems were demonstrated: Digital Energy Twins and Digital Energy Shadows. While in literature, the term "Digital Twin" is widely used as synonym, for rather different applications involving simulations and virtual models connected to real-world data, this paper elaborates on the differences between digital twins and digital shadows in more detail. Given by the complexity of real-world energy systems (heat and electricity) and their implications on real time simulation, the concepts are demonstrated on different TRL levels. The results show the benefits and limitations of Digital Energy Twin and Digital Energy Shadow applications in relevant environments.

INTRODUCTION

According to [1], the degree of data integration is used to characterize Digital Twins. A Digital Twin hereby consists of physical objects and digital objects, exchanging data either automatically or manually. If the data exchange between the physical and the virtual object in both directions is manual, e.g., using offline data exchange routines, this would be referred to as "Digital Model" or offline simulation. Rising the level of data integration to an automatic data flow from the physical to the virtual object leads to a "Digital Shadow". The virtual object (e.g., energy or heat simulation) follows the behavior of the physical object, represented through sensor data from the energy or heat network. The simulation is now online (automatically connected) to the actual sensor data. The highest level of data integration is reached when there is also an automatic data flow from the virtual back to the physical object. This closed loop data flow now enables a fully coupled status, where the behavior of the physical object (energy network) is controlled by the virtual object. This behavior is referred to as "Digital Twin". This work presents use cases for the two different situations of "Digital Shadows" and "Digital Twins".

The case of a "Digital Twin" is presented in Fig. 1. This case demonstrates the application of an energy-optimized production schedule. The main objective of the energy optimization is to minimize the total energy costs of the system. The main objective of the production schedule optimization is to achieve an optimal load profile of the factory. Developing a fully digital representation of the factory is challenging as modelling requires iterative development steps to improve, evaluate and revise existing models and data aggregation methods. Therefore, the Digital Twin was installed at the laboratory of FH Vorarlberg focusing on a lab-scale application.

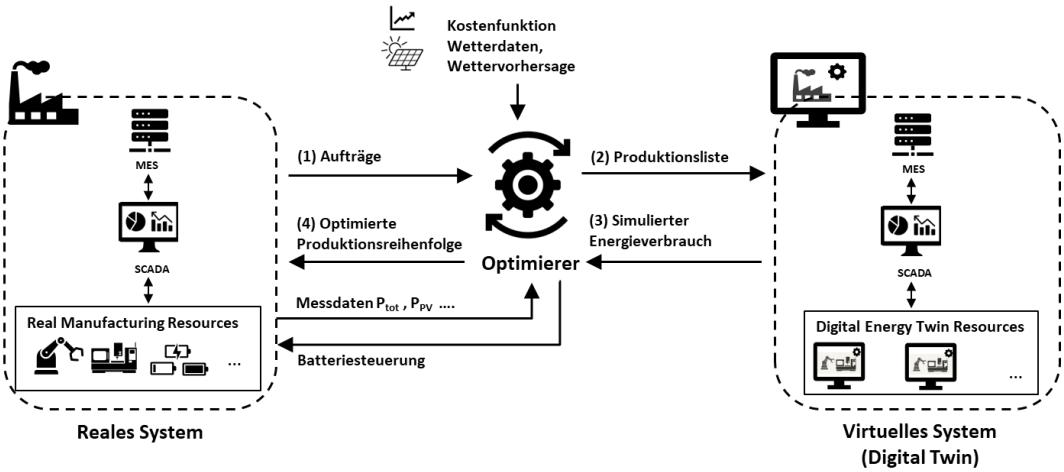

Fig. 1: Digital Energy Twin supporting decision-making on production planning

The case of a "Digital Shadow" is presented in Fig. 2. Compared to the "Digital Twin" in Fig. 1, there is no data flow from the virtual system back to the real system. This use case demonstrates an operations optimization of the energy supply network at AT&S with high complexity. The main objective is the definition of energy-optimal operation settings of the combined heat and power supply system.

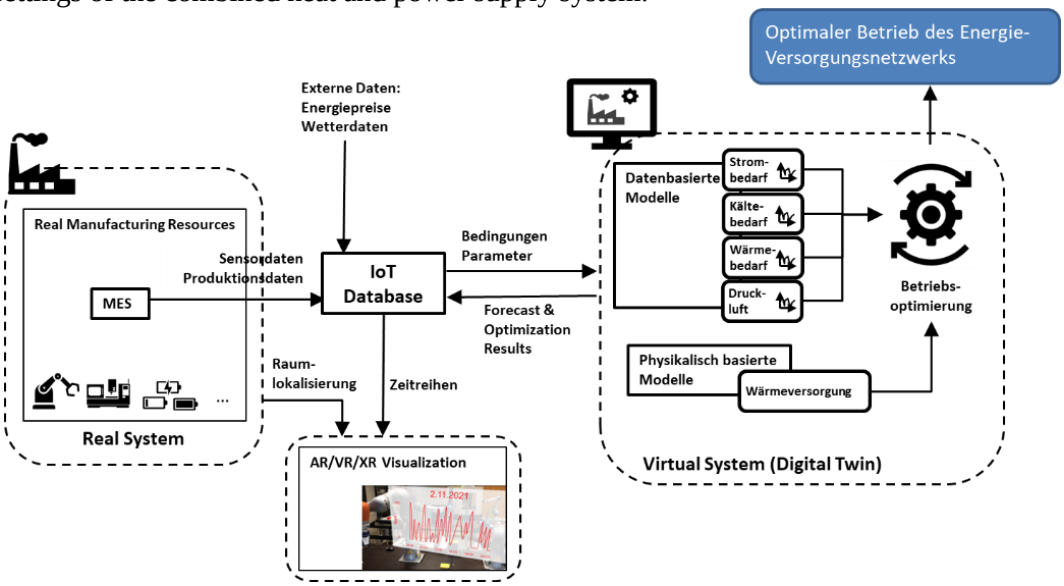

Fig. 2: Digital Energy Shadow supporting optimized operation of energy supply

This work describes the system concepts in more detail and presents implications on the development and integration of Digital Energy Twins/Shadows in real world applications. The complexity of the data management and system modeling requires specific considerations when dealing with such concepts.

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TACKLE THE BEAST – HOW TO ASSESS SCOPE 3 EMISSIONS

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SUMMARY

The transparent and valid measurement of Scope 3 emissions (indirectly caused emissions upstream and downstream) represents one of the greatest challenges for companies during their sustainable transformation. In order to assess the current performance of a company and to derive the necessary action steps, it is essential to have the best possible knowledge of the current emissions. However, especially in the area of Scope 3, companies are dependent on external information and are not in a position to independently determine the ecological footprints of upstream purchased materials, products and services and the downstream emissions caused by products and services sold. This publication provides an overview of current main challenges and complexities deriving from the assessment of Scope 3 emissions and highlights the most suitable approaches to achieve best possible results.

INTRODUCTION

In an effort to mitigate the challenges posed by climate change and environmental degradation, the European Union (EU) introduced the European Green Deal (European Commission, 2023) in December 2019. The overarching aim of the Green Deal is for the entire union to reach net zero emissions by 2050. With approximately 23 million non-financial enterprises (Statista, 2023) operating within the EU, measurement, monitoring and comparison of emissions data becomes a very complex yet essential task. The EU, therefore, has implemented the Corporate Sustainability Reporting Directive (CSRD) with the purpose of enhancing and standardizing corporate sustainability reporting. The directive aims to provide investors and stakeholders with improved information, increase transparency, and promote sustainable business practices. The specific guidelines for corporate reporting under the CSRD are outlined in the European Sustainability Reporting Standards (ESRS), covering various ESG issues, including climate change, biodiversity and human rights. Among its core elements is the transparent documentation of total corporate greenhouse gas (GHG) emissions. In accordance with the Greenhouse Gas Protocol (2011), greenhouse gas (GHG) emissions are categorized into Scope 1, 2, and 3 emissions (see Figure 1). Scope 1 emissions occur directly from sources that are owned or controlled by the reporting company and Scope 2 covers all indirect emissions via energy purchases in the form of electricity, heating, cooling and steam. Scope 1 and Scope 2 emissions are relatively easy to grasp and report. This is because the activities causing emissions are often billed with exact invoices and Scope 1 and 2 emissions data is easily available in public databases enabling accurate allocation and measurement of Scope 1 and 2 emissions. In contrast, all other emissions in a company's value chain ranging from upstream activities like mining of raw materials, manufacturing of purchased goods, transportation and distribution, and employee commuting and business travels to downstream activities such as transportation, processing, use and disposal of sold products, as well as investments or franchise operations. It is no surprise that in many companies, particularly in the manufacturing sector, the biggest share of emissions is generated through Scope 3 activities. However, most companies struggle to adequately report their scope 3 emissions because they operate within extensive supply chains which make it a challenge to track purchased and sold goods upstream and downstream in the value chain.

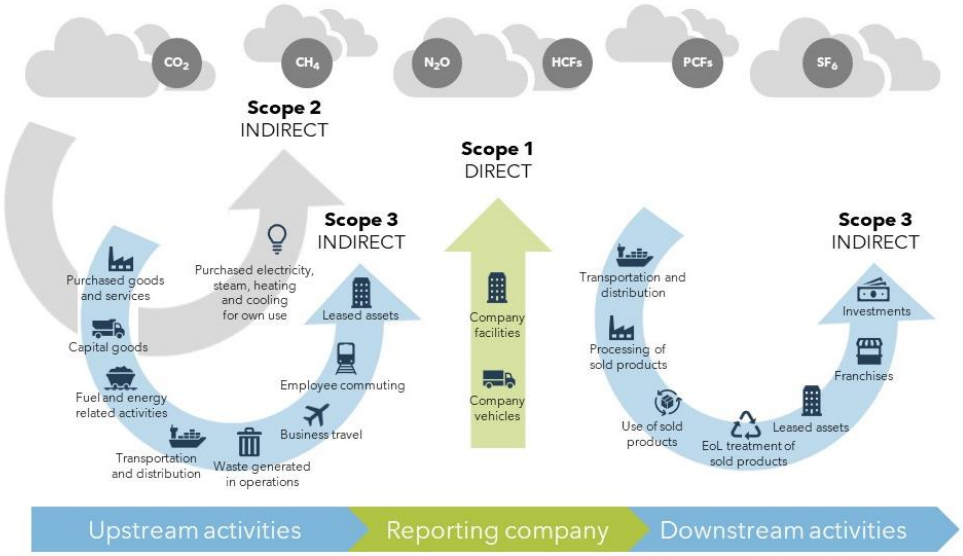

Fig. 11: Overview of GHG Protocol scopes and emissions across the value chain (Adapted from GHG Protocol, 2011)

In addition, suppliers often are not able to provide meaningful data or indications on emissions caused by their goods and services, increasing the dependency of reporting companies on the reporting capabilities and transparency of their suppliers. Lastly, not only data availability but also quality vary highly across geographies and data providers. Thus, collaboration among stakeholders and across supply chains as well as standardization efforts are essential to effectively allocate, measure and reduce all GHG emissions because only then we have a chance in reaching a net zero economy. The following section will outline a pragmatic and effective example on how to tackle the measurement of Scope 3 emissions.

MEASURING SCOPE 3 EMISSIONS IN DAY-TO-DAY BUSINESS OPERATIONS

Around 85% to 95% of a manufacturing company's emissions typically fall within Scope 3, although this percentage can vary, especially in heavy industries. In instances like steel or cement production, emissions within Scope 1 also contribute significantly to the manufacturer’s overall emissions. However, quantifying Scope 3 emissions often requires significantly more effort.

To illustrate, consider the case of a hypothetical company, Delta GmbH, a fictitious entity specializing in the production of metal components for the automotive industry. Headquartered in Austria, Delta GmbH operates production sites in Slovakia, Germany, and Thailand, employing 930 individuals and generating a global annual turnover of 220 million euros.

Table 1 serves as an example, detailing various sources of energy, materials, products, and services purchased by the company. The table provides information on the assigned scopes and the level of difficulty associated with data procurement and validation. It's important to note that every data point linked to Scope 1 or 2 contributes to Scope 3 as well, a consideration typically addressed by common tools for footprint assessment.

Table 1: Overview of different emission categories and their associated main scopes including the general difficulty of data procurement

Index	Category	Main Scope	Difficulty of data procurement (quantitative and qualitative)
1	Combustion of gas for heating and process energy	1	low
2	Electricity purchase	2	low
3	Fuel consumption in the company fleet	1	low
4	Flights (business travel)	3	low
5	Waste generation and treatment	3	low
6	Employee mobility on the way to work	3	medium
7	Purchased raw materials	3	high
8	Purchased components	3	high
9	Shipment of goods	3	medium
10	Usage of products (downstream)	3	high

In general, it can be asserted that categories indexed 6-10 are responsible for more than 75% of an enterprise's total emissions, as indicated in Table 1. However, accurately assessing these categories poses significant challenges. Therefore, how might a roadmap be devised to ensure a precise assessment of Scope 3 emissions? A pragmatic and highly effective approach to initiate the resolution of this issue is the application of the 80/20 principle. This principle, rooted in nature, dictates that 20% of a specific category contributes to 80% of the overall impact. For instance, in the natural world, 20% of Earth's species constitute 80% of the total species mass. This principle is universally applicable to every segment in the assessment of emissions. Notably, the mass of goods serves as a robust indicator of associated emissions. Within a company's list of purchased articles, the top 20% of items, sorted by descending mass, contribute to over 80% of the total emissions from all purchased materials. Using the example of Delta GmbH, a manufacturer of metal components, it is highly likely that over 80% of emissions within the raw materials segment can be identified within the initial items on the list. Embracing the 80/20 principle in emissions assessment offers a practical and efficient strategy, enabling enterprises like Delta GmbH to prioritize interventions for maximum impact. This approach optimizes resource allocation and enhances the efficiency of efforts to monitor and reduce emissions. In case the 80/20 principle does not prove to be helpful, an alternative approach is to initiate the assessment of Scope 3 emissions by focusing on monetary considerations, particularly the purchase volumes. Here, the prioritization of materials for emission assessment is determined by overall expenditures. Further details and guidance on the various approaches of assessing Scope 3 emissions will be provided in the keynote presentation.

In summary, the purpose of this presentation is to highlight the critical importance of addressing Scope 3 emissions in the context of mitigating climate change and the European Green Deal's ambitious climate goals, in particular. However, the complexity of Scope 3 emissions, especially within the manufacturing sector, poses challenges in measurement and reporting. Applying pragmatic approaches like the 80/20 principle offers an effective strategy to identify and prioritize interventions for maximum impact, optimizing resource allocation. This presentation titled TACKLE THE BEAST – HOW TO ASSESS SCOPE 3 EMISSIONS promises to provide detailed insights and guidance on pragmatic approaches, emphasizing collaboration, standardization, and the pursuit of a net-zero economy as essential components of successful emission reduction efforts.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

THE IMPACT OF HEATING & COOLING END USE ENERGY EFFICIENCY ON ENERGY SUPPLY

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SUMMARY

In 2018-2023, the European Union increased targets for GHG-emission reduction, energy consumption reduction, and renewable energy share. In this context, there are still questions regarding the implications of not meeting efficiency targets and the impact of different levels of electrification, district heating uptake, and biomass use, in particular for the heating and cooling (HC) sector. This paper addresses these questions using a multi-model framework for the EU27. Two models cover the demand side and two models cover the supply side. The framework is used to derive scenarios with different energy efficiency levels and technology uptake. The results show that higher energy savings in the scenarios lead to lower investments in renewable electricity generation and thus also pays off in economic terms. The scenario with high district heating has the lowest costs for required installed peak generation capacity.
Key words: EU-27, scenarios, modelling, H&C, industry, buildings, district heating, full energy system

INTRODUCTION AND RESEARCH QUESTIONS

In the period from 2018-2023, the European Union significantly increased targets regarding GHG-emission reduction, reduction of energy consumption and increasing the share of renewable energy. Member States have started to implement measures towards their implementation. However, the reporting, e.g. in the frame of the national energy and climate plans or the comprehensive assessment of efficient heating and cooling also shows a gap in the real implementation of policy measures on the ground.

This is also true for the heating and cooling (HC) sector, for which specific targets have been set. This includes the target of 49% share of renewables in buildings by 2030 or a binding target of 1.3 ppt increase annually for overall RES-HC.

REPowerEU scenarios showed the feasibility and impacts of these targets, including the HC sector. However, there are still open questions such as: What are the implications of not meeting ambitious efficiency targets on the other target achievements? What is the impact of different levels of electrification of the sector on the electricity system? What is the impact of different levels of district heating uptake on the whole sector and on the electricity system? What is the impact of different levels of biomass use for the sector and the upstream supply sector?

METHODOLOGY

This conference contribution focuses on these questions by applying a multi-model framework for the EU27 consisting of two models covering the demand side (Invert for buildings, Forecast-Industry for Industry) and two models covering supply side (Hotmaps-DH-gen for the district heating sector and METIS for the entire upstream supply sector).

We apply the described model framework to derive two main exploratory scenarios, showing different end-use energy efficiency levels: a moderate efficiency scenario and a high efficiency scenario. The latter is being used as a starting point for scenarios with higher biomass use and higher district heating.
In order to allow a maximum comparability across scenarios, only selected changes are made. Framework assumptions are defined equally for all scenarios based on the REPower EU Primes scenario Mix-H2.

RESULTS

Figure 1 shows the final energy demand by energy carrier for heating and cooling in industry and buildings for EU27 in the different scenario until 2050. The final results presented in this conference contribution will explain the impact of these scenarios on district heating supply mix and other upstream supply impacts, in particular requirements of renewable electricity generation and storage. They include a description of the scenarios both in terms of the energy system's characteristics as well as overall system costs.

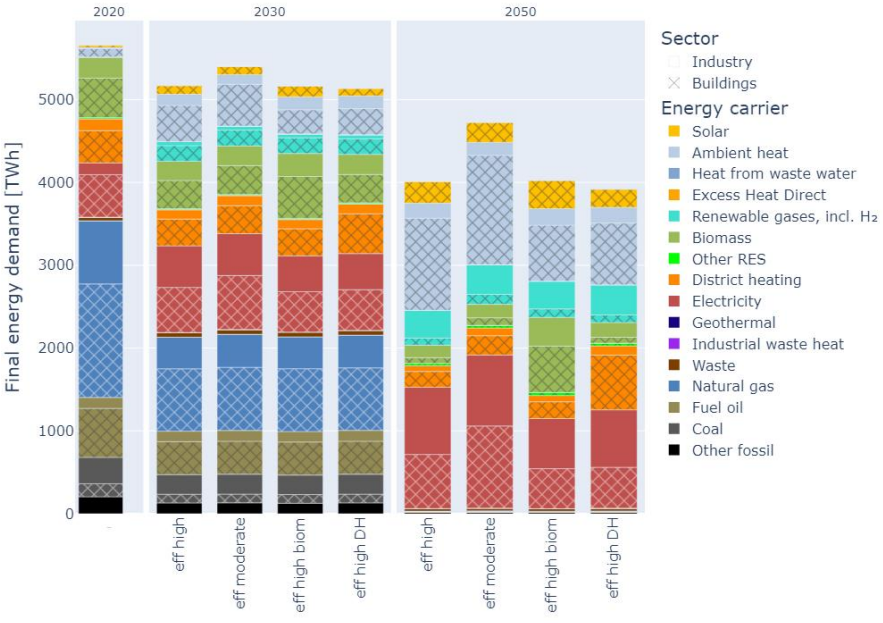

Fig. 1: Final energy demand heating and cooling in industry and buildings by energy carrier, technology scenarios, EU-27.

CONCLUSIONS

The results show that the energy savings achieved in the eff-high scenarios compared to the eff-moderate scenario lead to substantially lower investments required in renewable electricity generation. In particular for the scenario with high district heating (eff-high DH), due to the high uptake of deep geothermal resources or industrial waste heat, lower costs occur in the electricity generation, being reflected also in lowest costs for required installed peak generation capacity.

CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers: (i) Renewable heating and cooling, including high temperature applications, (ii) Solutions for Energy Efficiency, (iii) Policies

HEATING THE FUTURE: OVERCOMING CHALLENGES AND GAINING STAKEHOLDER SUPPORT FOR DISTRICT HEATING TRANSFORMATION

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SUMMARY

District heating plays an important role in many studies and scenarios for reaching greenhouse gas neutrality in the heating sector. In some cases, it accounts for up to 30 % of the final energy demand for heat supply in buildings. Expanding and transforming district heating will not occur effortlessly, so it will take a deliberate approach and appropriate measures to successfully achieve these goals. Technical and organisational challenges must be addressed, along with securing support and promoting social acceptance and sponsorship among the various stakeholders. Therefore, in this research, barriers, and potential solutions are analysed for the seven main stakeholder groups involved and affected by the extension and transformation of district heating in Germany. Furthermore, this study examines and discusses methods to increase acceptance and social sponsorship in Denmark, the Netherlands and France, based on literature, interviews and two stakeholder workshops. Consequently, measures to increase acceptance of and social sponsorship for district heating in Germany are formulated.
Key-words: District Heating, Stakeholder Analysis, Social Sponsorship, Acceptance, Political measures

INTRODUCTION

The transformation of district heating in Germany is essential to reduce greenhouse gas emissions in the heating sector. This includes building and expanding district heating systems as well as the integration of renewable energy and waste heat. It is a complex system transformation in which many stakeholders with individual interests and agendas are involved. To ensure the active support of all relevant stakeholders and increase acceptance, coordination and cooperation are necessary. While the energy transition discourse in the past has largely focused on technical challenges and solutions, socio-economic and socio-cultural aspects as well as possible conflicting goals were often neglected (Fraune et al. 2019). Yet, the transformation of our energy system is closely tied to social structures and requires the active support and personal contribution of the population. Therefore, considering acceptance as a multidimensional and complex construct (Wüstenhagen et al. 2007; Schweizer-Ries et al. 2008) and stimulating active participation of diverse societal stakeholders and institutions, appear as central success factors for the complex transformation of district heating.

STAKEHOLDER ANALYSIS

The analysed stakeholders involved in and/ or affected by the transformation of district heating in Germany are energy supply companies, municipalities, planning offices, SHK (sanitary, heating, air-conditioning) craft, building owners and tenants, (organized) citizens, associations, and other stakeholders. In this analysis, the various stakeholders are described according to their specific roles in the current system, actor-specific challenges, the required acceptance, and support services as well as facilitating factors. Challenges and strategies are clustered into the categories “social”, “psychological”, “organisational and planning”, “political”, and “economic”. Several approaches for increasing the social acceptance of district heating among all stakeholders were identified. Some approaches surpass acceptance and facilitate active social sponsorship. Major success factors and strategies to increase the acceptance in and support for social sponsorship of district heating include

municipal heat planning, transparency, consistent and target-oriented political frameworks, the reorganization of municipal financing, and financial support for participation in planning.

LEARNING FROM DENMARK, FRANCE AND THE NETHERLANDS

The objective of the district heating sector analyses conducted in Denmark, the Netherlands, and France is to examine and extract sector characteristics and advancements that may prove valuable to the discourse on the future development of district heating in Germany. In each country analyzed, we describe the market structure, political and regulatory framework, and main stakeholders to analyze and categorize the state of district heating development and its acceptance among various stakeholders. The most relevant findings are:

- Common understanding of goals in the area of heat supply across all federal levels and political affiliations positively affect the transformation of heat supply.
- Municipalities are the central stakeholders in the expansion and transformation of district heating. They must be put in a position to fulfil this task. Financing of their tasks must be provided by national bodies rather than using the revenues from district heating.
- Active participation and financial opportunities for the population are important for increasing acceptance of district heating and for achieving social sponsorship of the transformation at the local level.
- Appropriate price regulation and price transparency are paramount to the market acceptance and trust in district heating, as they operate as local monopolies.

POLITICAL MEASURES TO INCREASE ACCEPTANCE AND SOCIAL SPONSORSHIP

Based on the analysis of the stakeholders in Germany and experiences in Denmark, France, and the Netherlands, five measures are identified as essential and supportive for increasing acceptance and social sponsorship. For these measures central elements are developed and described, which are: goal, impact, qualitative description, concrete possibilities for connection to the regulatory framework, time required for implementation, and time horizon of the impact. The measures are systematic learning, price transparency, price regulation, transparency, and financing participation processes.

CONCLUSION

District heating is projected to gain significant importance in the future based on extensive scientific studies. The transformation and expansion of district heating require the support of various stakeholders, whose active involvement and acceptance are critical. Both can be supported by a consistent and targeted policy framework committed to promoting and expanding district heating. The identified measures show great potential to increase the acceptance and social sponsorship of district heating among several relevant stakeholders, especially district heating companies, municipalities, and consumers. These measures can be implemented comparatively quickly and bear the potential to have a long-lasting positive impact.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers: Policies; alternatively: Future District Heating and Cooling Technologies

CCU AND CCS PERSPECTIVES FOR AUSTRIA

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SUMMARY

Carbon Capture and Utilization (CCU) and **Storage (CCS)** are considered necessary to achieve **net zero emission goals**. While the technologies offer many opportunities, their development and implementation face various challenges with regard to their technoeconomic and ecological impacts as well as framework conditions. For **Austria**, these challenges were insufficiently assessed so far. Thus, the ACRP project CaCTUS develops and evaluates a variety of "CO_2 source-to-sink routes" tailored to the Austrian situation. Special focus is on the long-term availability of CO_2 emissions and demand, available technologies, and **technoeconomic aspects**, the **mitigation potential** and **legal/regulatory implications**.

INTRODUCTION

Achieving the Paris climate goals of limiting global warming to <2°C is considered one of the greatest global challenges. At the same time, scientific evidence is mounting that the time remaining to stabilize the climate is severely limited (Lee et al., 2023). Academic work analyzing G20 climate policies from 2000-2019 finds that there are still significant gaps in defining action in several sectors (Nascimento et al (2021)). In addition to emission reductions, CCU and CCS are considered essential to achieve global climate targets (IPCC, 2021). For this purpose, the climate protection potentials of individual technologies and their application potentials have to be evaluated. Therefore, potential long-term CO_2 sources and sinks, the corresponding capture efforts and the time periods of sequestration must be assessed. Furthermore, it is critical to assess further associated environmental impacts and how the legal framework must evolve. These issues have been insufficiently addressed for Austria so far, and the political debate on a National Carbon Management Strategy has just started (September 2023) (BMF (2023)). While fast action is needed to achieve the climate goals, decision-makers should rely on sound scientific analysis to identify relevant technologies and their long-term feasibility, as well as their potential shortcomings. CaCTUS (2022) supports this process in Austria by providing a comprehensive analysis of available CCU/CCS technologies under public framework conditions, but especially to assess the CCU/CCS potential for the public climate-neutrality long-term strategy and to develop recommendations for the necessary economic and political framework conditions.

METHODOLOGY

The project follows a step-by-step approach to assess the CCU/CCS potential in Austria and to derive recommendations for policy makers and other stakeholders. For this purpose, CO2 sources and sinks are evaluated and compared via scenario analysis (current, 2030, 2040, 2050) based on Austrian transition scenarios (NEFI (2023), BMNT (2019), BMK (2023)). Actual and potentially remaining CO2 emissions are estimated based on current CO2 sources based on statistics and literature (e.g., UBA (2023), EBA/GIE (2023), BML (2022)) and projected technological developments. As potential CO2 sinks a variety of industrial processes (chemical industry, e-fuels i.a.) and geological storage are being evaluated.
Subsequently, CCU/CCS pathways (see Fig. 3 below) tailored to the Austrian conditions are developed and evaluated based on available information on technological maturity, techno-economic indicators and

environmental goals. In addition, a comprehensive analysis of the EU and Austrian legal framework for CCU/CCS applications is conducted using literature and case law research as well as legal interpretation methods.

RESULTS

Despite all efforts made to reduce the use of fossil fuels in Austria, the results derived in the CaCTUS project show, that there are additional measures required to achieve actual climate-neutrality. Particularly for the industry and energy sector it is shown that climate-damaging emissions cannot be fully avoided by fuel and/or process adaptation. On the one hand, the production of cement clinker, ceramics, and glass is afflicted with geogenic CO_2 emissions from the processed minerals, which are expected to remain to an extent of approx. 2 800 kt per year. On the other hand, the end-of-life utilization of originally fossil-based products in a waste-to-energy manner will add to fossil emissions beyond the substitution of fossil feedstock. By 2050, fossil emissions of at least 1 600 kt per year are expected to remain. On the contrary, an increase of climate-neutral biogenic emissions by at least +23 % is expected, resulting from a stronger use of biomass-based energy carriers and an intensified production of those (CO_2 from fermentation).

From these results it becomes obvious that mechanisms for a long-term fixation of remaining CO_2 emissions are required to effectively achieve climate neutrality. Furthermore, as available capture technologies involve certain capture rates, which prevent a full separation, this also involves capturing of already carbon-neutral emissions (i.e., biogenic) and/or atmospheric CO_2 to some extent. While storage capacities in Austria were found to be rather limited at approx. 120 Mt (Welkenhuysen et al., 2016), there is also a certain demand for CO_2 as feedstock for carbon-containing products within a carbon-neutral energy system. To produce sustainable base chemicals alone, an annual CO_2 demand of approx. 3 300 kt is expected, if appropriate CCU pathways are followed (based on Tian et al. (2015)). Consequently, a corresponding carbon management strategy will be required for Austria, which must include defined pathways to omit the release of said CO_2 emissions to the atmosphere a priori by implementing measures for carbon (re-)cycling, as well as potential extraterritorial options for storage or utilization. The assessments performed in the CaCTUS project therefore suggest appropriate source-to-sink routes along with their feasibility from a techno-economic and ecological perspective.

The results gained in the project are further transferred to distinct recommendations for a supportive and target-oriented implementation of CCUS activities in Austria from a holistic perspective. In that context, accompanied assessments of legal and regulatory frameworks point out existing barriers preventing a rapid implementation. A key issue in the use of CO_2 is the question of who has to surrender certificates for which quantity of CO_2 and when, within the framework of the European Emissions Trading Scheme. Regarding the permanent geological underground storage of CO_2, the Austrian legal situation currently provides for a ban, although the partial lifting of this ban is currently under discussion.

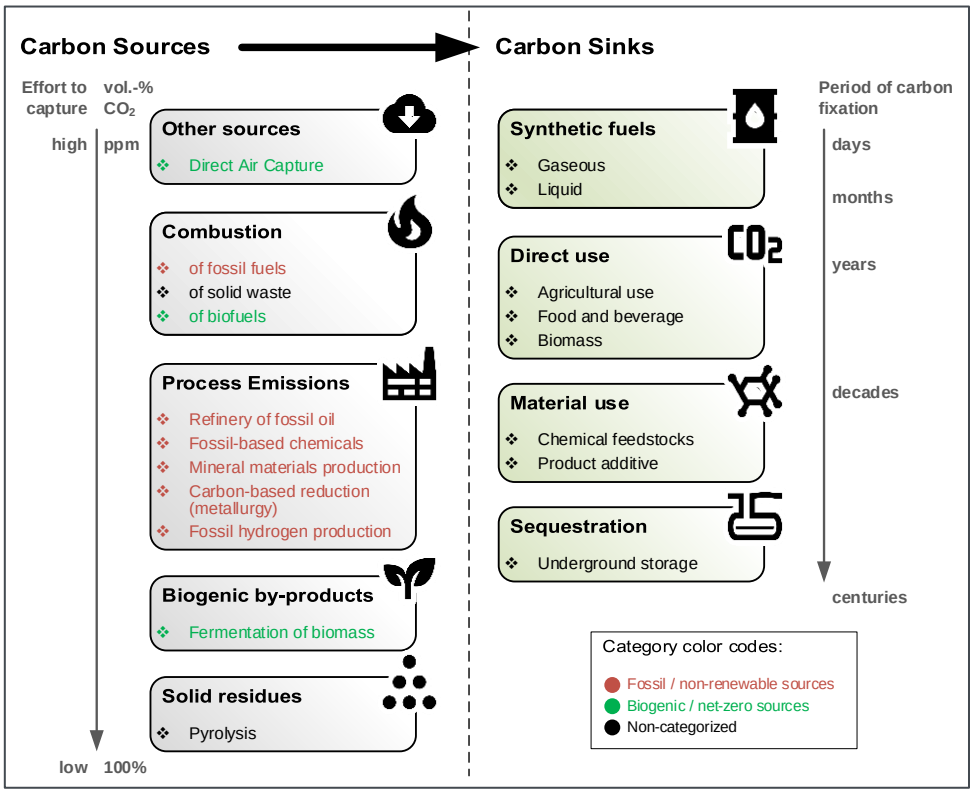

Fig. 3: Variety of CO_2 point sources with different concentrations and potential carbon sinks with varying fixation period. Source: Own illustration.

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CONFERENCE TOPIC

Approaches towards net-zero/negative emissions in the industry including CCU

REA: RESOURCE EXERGY ANALYSIS - A KEY TO CLIMATE SUSTAINABILITY

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SUMMARY

Resource exergy analysis (REA) is a method to comprehensively assess the resource consumption of technical systems. It is based on the physical property "exergy", which goes beyond conventional energy analysis by considering energy quality. Combining exergy with a scientific definition of natural resources, REA can provide a comprehensive quantification of the resource consumption caused by any demand. REA introduces resource exergy consumption as a new key metric for the assessment of technical systems. In combination with an assessment of the direct greenhouse gas emissions it allows to consistently quantify climate sustainability. The use of REA can be a key to climate sustainability by helping to minimize wastefulness and as a consequence indirect greenhouse gas emissions.

INTRODUCTION

The central goal of the energy transition is achieving climate neutrality as fast as possible. A realistic and target-oriented assessment of energy systems is key to achieving this objective.
With the increasing use of non-fossil sources, problems with existing evaluation systems for energy products and energy consumers become more relevant. In particular, the following are worth mentioning:

1. Non-renewable primary energy factors do not adequately consider the climate impact. For example, natural gas and hard coal are valued the same. Furthermore, they do not allow for differentiation of renewable energy supply systems.
2. Total primary energy factors are usually not suitable for assessing overall efficiency. Energy from solar thermal, waste heat, photovoltaics and natural gas are rated approximately the same.
3. Greenhouse gas emission factors cannot contribute to the effective implementation of the "efficiency-first" principle for energy systems that emit low amounts of greenhouse gases. Thus, despite much greater inefficiency, the combustion of green hydrogen in boilers would be considered almost equal to the use of green electricity in heat pumps using this indicator.
4. The indicator "share of renewable energies" is misleading in some cases. Even systems with high shares of renewable energies can contribute significantly to ecological damage, e.g. when using palm oil from former rainforest areas.

A sound solution to these problems is the combination of two, independent, reality-based indicators.
The frequently used non-renewable primary energy factors can be replaced by realistic greenhouse gas emission factors. However, these only allow an estimate of direct emissions.
The comprehensive implementation of the "efficiency first" principle is only possible through an additional assessment of the resource exergy consumption (REC). The physical quantity exergy, which considers not only energy but also energy quality, combined with suitable balance boundaries provides an optimal basis for this.
Furthermore, reduced REC helps to minimize indirect greenhouse gas emissions. This effect is caused by the demand-oriented supply usually expected from energy systems. If demand always needs to be covered, and all greenhouse-gas-neutral energy sources are used as intensively as possible, then any wastefulness leads to an increased use of other, usually fossil resources somewhere in the supply chain. This in turn causes indirect emissions due to resource wastefulness.

DEFINITION

To assess resource exergy it needs to be defined in a consistent way. Commonly, a resource is understood to be a naturally existing stock of something that is [constantly] needed for a specific purpose, especially for human nutrition and economic production. Resource exergy is the exergy associated with this stock.
Resources can form a stock in the present form. As input flows of resource exergy (RE), only energy flows are considered that can be stored directly in their present form without further conversion or transmission.
Energy flows that are lost to the global technical energy system if they are not used directly, such as solar energy, kinetic energy of wind and water currents, and geothermal and waste heat, do not constitute stocks and are therefore not considered resources.
In these cases, where the primary energy cannot be stored without conversion or transmission to a technical system, the first secondary energy that can be stored directly, without conversion or transmission, is considered a resource.
This means that when generating electricity from solar radiation or the kinetic energy of wind or river water, the electricity generated is considered a resource.
In the case of solar thermal systems, the hot water produced with it at a certain temperature level is considered a resource.
The resource potentially provided by waste heat and geothermal energy is the heat after transfer to a technical system (e.g. a water circuit). Waste heat is considered in the same way as geothermal energy, with the difference that the effort required to transfer it to a technical system is usually much lower. The necessity of releasing waste heat to the surroundings of the waste heat generator allows considering it as if it is extracted from the environment, thus making it a quasi-natural energy source.
Water in reservoirs represents an artificially generated resource, as the storage of water preserves part of its original potential energy, e.g. water in mountains. Accordingly, when considering water from reservoirs, losses in the conversion of potential energy into electricity must be properly considered for the determination of RE.
Thus, natural fuels represent the only naturally occurring resources for the energy system, as they are already stored as they are, without transfer to a technical system. This includes fossil, biogenic and nuclear fuels.

APPLICATION

One goal of REA is to help assess climate sustainability. This is achieved by calculating resource exergy consumption (REC) in parallel to the greenhouse gas emissions (GHGE) caused by a considered energy system that supplies a given demand. REC and GHGE are complementary metrics for any energy system scenario. Thus alternative energy systems – such as existing and possible future ones – can be compared. This in turn allows the identification of the least wasteful and polluting systems enabling decision makers to favor these systems above less sustainable ones. A detailed guide to assess all types of energy systems (Jentsch, 2023) is available since 2023 to allow consistent quantitative comparison of all potentially viable energy systems on an individual, communal and even international scale.

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CONFERENCE TOPIC

Life Cycle Assessment

COMPLEXITY OF LIFE CYCLE ASSESSMENTS FOR CO_2 TECHNOLOGIES

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SUMMARY

Accurately assessing the carbon footprint of a product or process is critical but there is ongoing confusion about how to conduct life cycle assessments when CO_2 is involved. It is also often overlooked that the nature of a particular source of CO_2 plays a key role in the environmental impact and economic viability of a technology. In the discussion of climate change, frequently, LCA is understood as focused on CO_2, but a comprehensive LCA must address additional impacts, e.g. water use, toxicity, amongst others. Lastly, inclusion of societal aspects into LCAs for CO_2 technologies is at present underdeveloped at best.
Key-words: Life cycle assessment; carbon capture, utilization, and sequestration; multi-functionality; economics

INTRODUCTION

The focus on carbon dioxide in the context of climate change mitigation is essential. Urgent large-scale action is needed to curb further emissions, to remove at least to the extent possible so-called legacy emissions from air and water, and to implement the use of CO_2 as a non-fossil carbon source to produce essential products. To achieve this, a collection of approaches is needed to supplement other efforts to achieve net zero carbon emissions: carbon dioxide capture, utilization, and sequestration (CCUS). Accurately assessing the carbon footprint of a product or process is critical in these contexts but there is ongoing confusion about how to conduct life cycle assessments when CO_2 is involved.

LCA GUIDELINES AND STANDARDS

A clear need for harmonized assessment guidelines has been articulated and international efforts have been underway for quite some time with excellent progress towards more clarity for those who conduct studies and those who commission studies and have to act upon the results. (1–4)

In deciding whether to pursue a particular technology, the specific combination of CO_2 sources and sinks (a "usage pathway") determines the environmental impact, economic viability, overall role in climate change mitigation and continued availability of carbon-based products. Optimal deployment requires a clear understanding of the nature of carbon sources and the durability and economic value of downstream processes and materials. A high-level summary as a starting point is shown in Figure 1. Project-specific analysis is always needed to make a final determination about benefits and risks.

Established ISO standards define how life cycle assessments should be conducted in general. (5,6) In the context of CCUS technologies and products, however, these standards leave ambiguity due to multi-functionality of CO_2, amongst other issues. Those ambiguities have been addressed in a community-based guidelines document that provides comprehensive definitions and descriptions for LCA for CCUS (2) and there is ongoing international coordination to refine implementation. (4)
The inclusion of societal aspects into the framework of LCAs is pivotal for fast technology deployment and has recently been recognized as a key topic for future work on advancing LCAs. (7)

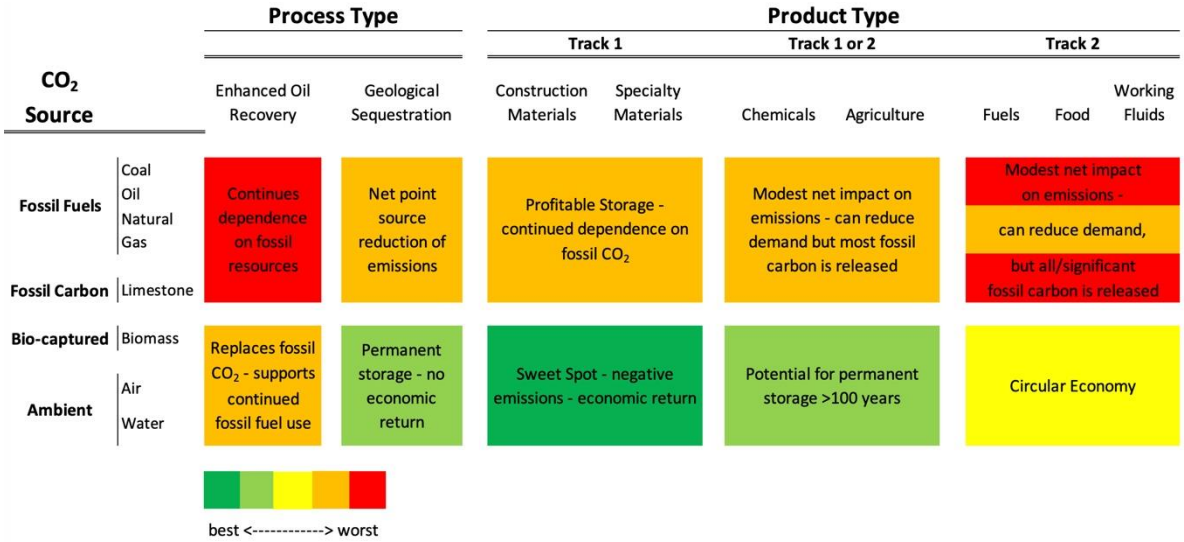

Fig. 1: The environmental impact and economic viability of CCUS technologies critically depend on the source of the CO_2 and its downstream fate. (8)

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CONFERENCE TOPIC

Life cycle assessment

INVESTIGATION OF THE FLEXIBILITY POTENTIAL BY DECOUPLING BUILDING MASS AND ROOM TEMPERATURE

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SUMMARY

Using the thermal building mass as a thermal storage received increasing attention in research during recent years. Due to the large mass of concrete, the buildings mass offers a large storage capacity and thus a high potential for flexibility. Especially for Air-Source Heat Pumps (ASHP) this can be beneficial to improve the efficiency, reduce electric peak loads and increase the self-consumption rate of onsite renewable energy sources. One limitation of using the thermal building mass as a thermal storage is the thermal comfort of the occupants. In a field test a thermally activated building system (TABS) is investigated which decouples building mass temperature and indoor room temperature. In this contribution the energetic potential of the TABS is investigated utilizing a simulative parameter study. A first static analysis shows an increase of up to 7,5 % in usable storage capacity compared to a usual TABS. Due to the high thermal inertia of the building mass, dynamic effects can offer an even higher potential and be also part of this contribution.

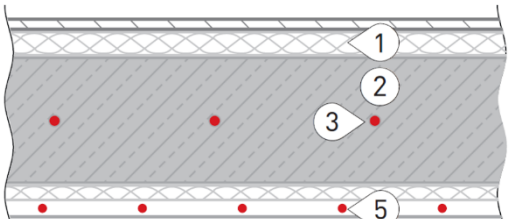
INTRODUCTION

The flexibility of a building was investigated in the programme of IEA EBC Annex 67 in detail. According to the summary report, a building can offer different sources of flexibility in its energetic usage. Besides a water-storage or an electro-chemical storage (e.g. battery), the building mass itself can also be used to provide flexibility options. [2]

Using this flexibility is especially beneficial for ASHPs as they depend on the fluctuating temperatures of the ambient air. Thus, shifting the operation time of an ASHP has a major impact on the efficiency which is highly dependent on the source temperature. This may also influence resulting peak loads in the electric grid and the self-consumption rate of onsite renewable energy sources (e.g. PV-system). In a simulative study the potential of activating the building mass was investigated [3]. It was shown that the self-consumption rate of a single-family home (SFH) could be increased by 50% using floor heating as TABS and an additional water-tank.

However, in a review of capabilities and limitations of TABS one major limitation identified by the authors is the thermal coupling of building mass temperature and indoor room temperature [4]. This means that a charging of the building mass typically results in a higher room temperature. Thus, the maximum possible temperature of the building's concrete is mainly limited by the thermal comfort of the occupants.

In the framework of a research project a thermal activation concept is investigated which decouples both, the building mass and the indoor room temperature using an insulation layer, see Fig. 1.



1: insulation layer
2: concrete layer
3: concrete core activation
5: space heating layer

Fig 12: Schematic cross-section of the concrete core activation concept with additional insulation layers to thermally decouple the indoor room air and the concrete core, in accordance to [1]

On the one hand, this enables a higher temperature of the building mass and thus a larger usable storage capacity for load shifting. On the other hand, a modified hydraulic cycle is needed to cover the heat demand during peak loads. The latter leads to an increase in pump operation time and thus may have a negative impact on the operational energy consumption of the system. This is investigated within the proposed contribution by means of a simulative parameter study based on a validated simulation model.

METHODOLOGY

In the framework of the field test first a monitoring concept was developed to measure the dynamic behaviour of the described TABS. Using energy meters, fluxes of thermal and electric energy are monitored. The room temperatures of every room in the building are monitored along with further comfort specific values (e.g. CO_2, Volatile Organic Compounds, rel. humidity, …). During construction phase, temperature sensors were installed inside the concrete core to measure the temperature of the building mass.
Furthermore, a system simulation model of the monitored building was set-up in MATLAB/Simulink using the CARNOT Toolbox [5]. The building model includes two temperature zones, one for each heated floor. Also, the TABS was modelled using an RC-modelling approach.
Using the measurement data of the upcoming heating season 2023/2024, the behaviour of the building and the heat losses of the TABS will be evaluated and used as an input for the model validation. Based on static and dynamic simulations, the impact of an insulation layer in a TABS is investigated to decouple the building mass from the indoor room temperature. The potential will be evaluated by means of building mass and indoor room temperature, and the operation of pumps.

PRELIMINARY RESULTS AND OUTLOOK

In a static simulation a TABS including an insulation layer of 4 cm and a thermal conductivity of 0.17 W/mK was compared to a TABS without insulation layer. The results show that by using an insulation layer the building mass temperature could be increased by up to 7.5 % without affecting the indoor room temperature. A higher temperature of the building mass allows more thermal energy to be stored in the concrete. Due to the high thermal inertia of the building mass, dynamic effects offer an even higher potential and will be investigated in annual simulations.
In this contribution, also preliminary results from the field test will be shown and discussed based on measurement data which are recorded in the upcoming heating season (2023/2024).

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications; Solutions for Energy Efficiency; Flexibility and Stability of Thermal and Electric Grids.

ENHANCING CLIMATE RESILIENCE AND ENERGY FLEXIBILITY OF BUILDINGS AND ENERGY SYSTEMS BY COMBINING COLLECTIVE INTELLIGENCE AND REINFORCEMENT LEARNING

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ABSTRACT

Climate resilience of urban energy systems is an important growing topic [1]. Increasing the energy flexibility of the grid is a key towards higher resilience as well as integration of renewable generation [2]. In urban areas, optimizing the energy performance of buildings in a collaborative manner helps a lot to reach a higher energy flexibility and climate resilience without investing a lot on energy infrastructure, as long as the provided solutions are affordable and practical [3]. In this regard, we integrated core elements of collective intelligence (CI) and reinforcement learning (RL) and introduced a novel energy management (EM) approach, calling it CIRLEM [4]. It operates based on distributing a flexibility signal through the grid, asking agents to adapt their energy performance to the new conditions. The flexibility signals reflects upon the collective behaviour of the grid while agents decide separately using a value-based model-free RL engine. We have tested the performance of CIRLEM in a large elderly building in Norway for future extreme warm summers and extreme cold winters. In this work, we expand the application of CIRLEM towards the energy management of a typical urban area in Stockholm, Sweden. The focus is on investigating the performance of CIRLEM over whole year, considering typical, extreme warm and extreme cold weather conditions in the future. Multiple building control strategies, such as changing the indoor set-point temperature, ventilation rate, and window shading, are considered as adaptation strategies. CIRLEM's performance will be assessed using two different approaches for controlling the buildings (or agents). The approaches are based on doing all the decision making only at the edge node (Edge Node Control or ENC) or together with the cluster (Edge node and Cluster Control or ECC). It is expected that the differences between two approaches become more visible over typical weather conditions and not during extremes.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:
Digitalization for Future Energy Systems

DIMENSIONING METHOD FOR PVT COLLECTORS AS HEAT SOURCE OF HEAT PUMPS FOR RESIDENTIAL BUILDINGS

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SUMMARY

Photovoltaic-thermal (PVT) collector is an emerging technology that is increasingly being used as a heat source for heat pump systems in residential buildings. However, a suitable methodology for sizing the PVT collectors for these systems is still missing. This paper initially provides a framework for the sizing a heat pump system according to the German standard VDI 4645. Furthermore, based on the selection of the heat pump and its operating characteristics at design conditions, the required area of PVT collectors with given thermal performance parameters is determined. Different heat pump operation modes i.e. monovalent or bivalent are also considered. These design steps consisting of VDI 4645 and the sizing method for PVT collectors are incorporated in a web-based tool that is aimed to assist planners (or homeowners) during preliminary planning of a heat pump system in single and multi-family houses. The tool also covers the planning of systems with backup/additional heat sources (e.g. gas boiler and heating rod) for bivalent systems or buildings with limited roof areas for PVT installations.

Keywords: *PVT collectors, heat pumps, VDI 4645, heat load, dimensioning, operation modes*

INTRODUCTION

Heat pumps are considered to be one of the key technologies for achieving climate targets in the building sector by reducing primary energy consumption and CO_2 emissions. Due to the noise limitations and relatively lower efficiencies of air source heat pumps, brine-water heat pumps with various sources are increasingly used. Brine-water heat pumps are mainly coupled with geothermal sources such as borehole heat exchangers (BHE) and horizontal ground heat exchangers (HGHE). In recent years, PVT collectors have also been increasingly used as a heat source for brine-water heat pumps. Monitoring and simulation results show that the PVT collectors could be a key technology as a heat source for the heat pump, providing better system efficiency than air-source heat pumps and can cut off CO_2 emissions even more than ground-source heat pumps (Chhugani et al., 2023).

This paper is based on the results of the ongoing project "integraTE", which focuses on PVT heat pump systems and aims to increase the market penetration of technically and economically attractive energy supply concepts with PVT in the building sector. In this context, there is a need for a method for sizing the components of a PVT-heat pump system (as shown in Figure 1) in residential buildings.

The existing German guideline VDI 4645 (2016) provides a framework for the planning and dimensioning of heat pumps based on the demands for space heating and domestic hot water at the design point. This work presents the adapted method for brine-water heat pumps with PVT collectors as heat source.

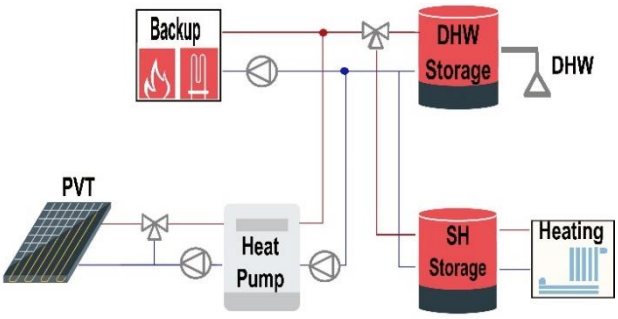

Figure 13: Schematic representation of the PVT-heat pump system covered by the dimensioning method

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METHODOLOGY AND EXPECTED RESULTS

Figure 2 illustrates the structure of the methodology implemented in a web-based tool. The user inputs to the tool include the information about building such as heat load number of residents, and number of apartments for multi-family houses. Further information about the location and design weather conditions i.e. the standard outdoor temperature, irradiation, wind speed and balance point temperatures must also be specified. The desired operation modes (monovalent or bivalent), method of heating (radiator/floor heating), the shut-off periods specified by the utility and the temperature levels on the domestic hot water and space heating storage tanks are also the inputs to the tool. The above-specified inputs from the user are processed using the mathematical models and procedures specified in VDI 4645 to size the storage tanks for space heating and domestic hot water preparation. Then, the tool estimates the dimension of the heat pump, which is sufficiently large to meet the heat requirements based on the operation modes and shut-off periods. Once the heat pump is dimensioned, the information about the heat pump and its characteristics under the design conditions has to be specified by the user. The weather conditions at the design point are necessary to calculate the thermal output (in kW) per m2 of PVT based on mathematical model specified by ISO 9806 standard and the thermal performance parameters of the chosen PVT collectors. In the context of bivalent systems, the size of a backup heater is calculated based on the heat demand that the heat pump does not meet at the design point. Furthermore, this design method will be validated through dynamic system simulation technique and the results will be included in the long version of the paper.

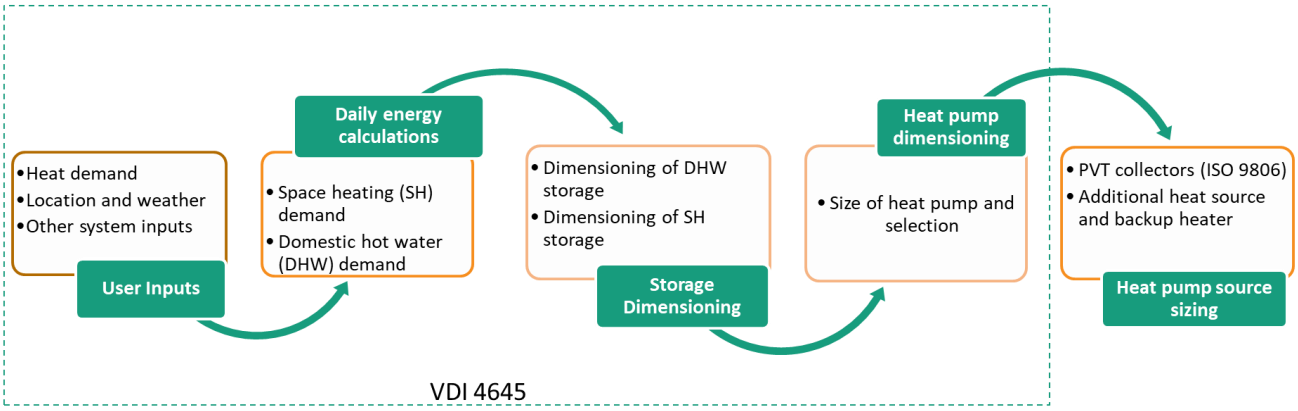

Figure 14:Methodology for dimensioning of heat pump system

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CONFERENCE TOPIC

Renewable heating and cooling, including high-temperature applications

STEPS TO CO_2- NEUTRAL CITY DISTRICTS – LEARNINGS FROM POST CITY GARDENS LINZ

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SUMMARY

In the Post City Gardens in Linz, new mixed-use quarter with 150000m² GFA will be developed in the next few years. Using this quarter as an example and input parameter source, an interdisciplinary project explored concepts for a climate-neutral neighbourhood energy supply that is implementable in combination with building greening, diverse biodiversity measures and profound rainwater management. Synergies with nature based solutions and the possibilities and steps to reach CO_2 neutral energy supply were worked out and summarized into an implementation concept which shows multipliable solutions for future developments of sustainable, climate-neutral urban and rural neighbourhoods. *Renewable energy districts, sustainable urban quarters, decentralized energy supply, nature based solutions.*

INITIAL SITUATION AND MOTIVATION FOR THE R&D PROJECT

Energy used for constructing, heating, cooling and lighting homes and businesses, as well as the appliances and equipment installed in them, accounts for 36% of the world's final energy consumption and the respective emissions (1). Furthermore, the energy demand of the world´s building sector increased more than 20% between 2000 and 2017(2). Therefore, it is inevitable to change the way we think the energy supply of city districts if we want to achieve our climate goals. The former postal distribution center next to the Linz train station is currently undergoing a fundamental transformation from a completely sealed infrastructural wasteland to **a mixed-use quarter with approximately 150,000m² of gross floor area**. An innovative mix of office, commercial, hotel, infrastructure and residential uses in 11 large-volume buildings and green spaces on several levels will be built over the next few years. Thanks to their central location, these "Post City Gardens" offer excellent conditions for the development of a neighborhood that is **innovative from the ground up and conserves energy and resources**. To seize this unique opportunity, an exploratory research project was initiated by Post AG together with the planning team and specialists in energy, greening and biodiversity.

PROJECT CONTENT AND OBJECTIVES

The project focused on developing a **bundle of measures for sustainable city quarter design** as part of a systematic approach**.** The goal to deeply explore the steps towards **a CO2-neutral energy supply and innovative energy management** was reached considering complementing topics such as building greening, biodiversity and rainwater management. In addition to examining the possible individual measures in detail, such as photovoltaics, geothermal energy flexibilized by an anergy network, wastewater heat or sources for the regeneration of probe fields, the focus was also laid on the **integrability of the topics** energy supply, building greening and urban climate in the constructional realization and the **ecological and economic effects**.

METHODICAL APPROACH

First, an analysis of the existing preliminary design plan and calculations of the future energy demand were conducted. In a step-by-step approach, detailed calculations of solar energy potentials followed by geothermal energy estimates and probe performance simulations were performed. The locally available renewable energy

was compared to the estimated seasonal demand and ways to synchronize the two were explored by simulations and use of empirical data. Potentials for wastewater heat recovery, in-house and from external sources were studied to further minimize CO_2-emissions. Possible synergies with building greening were explored. Finally, an integrated concept adapted to the specific architecture was developed in interdisciplinary planning meetings. The use of ecological assessment tools and life cycle cost analysis supported the decision-making processes.

RESULTS AND CONCLUSIONS

The development of a **cycle-oriented local energy concept using geothermal energy, photovoltaics and heat recovery from wastewater** reduced the calculated annual CO_2 emissions by almost 90% in comparison to a district heating and cooling concept based on external energy supply. The remaining 10% are due to the unavoidable demand for externally generated electricity, which is not fully produced without using fossil energy yet. In the energy planning of such overall quarters, there is a great challenge in the **conflict between the standard-compliant design of the heating and cooling systems and the actual demand in the utilization phase**, which is not yet precisely known during the planning stage and tends to be overestimated in the case of ÖNORM-compliant calculation. This can lead to ecologically and economically disadvantageous solutions.
The present project also showed that the professional exchange between energy experts, architects and greening, biodiversity and rainwater specialists at an early planning stage of such quarters is absolutely recommended to achieve ecologically, economically and architecturally appealing overall solutions without costly re-planning at later stages. The elaborated final concept shows **multipliable solutions** for the development of sustainable, resilient neighborhoods ready for a climate neutral future.

FIGURES

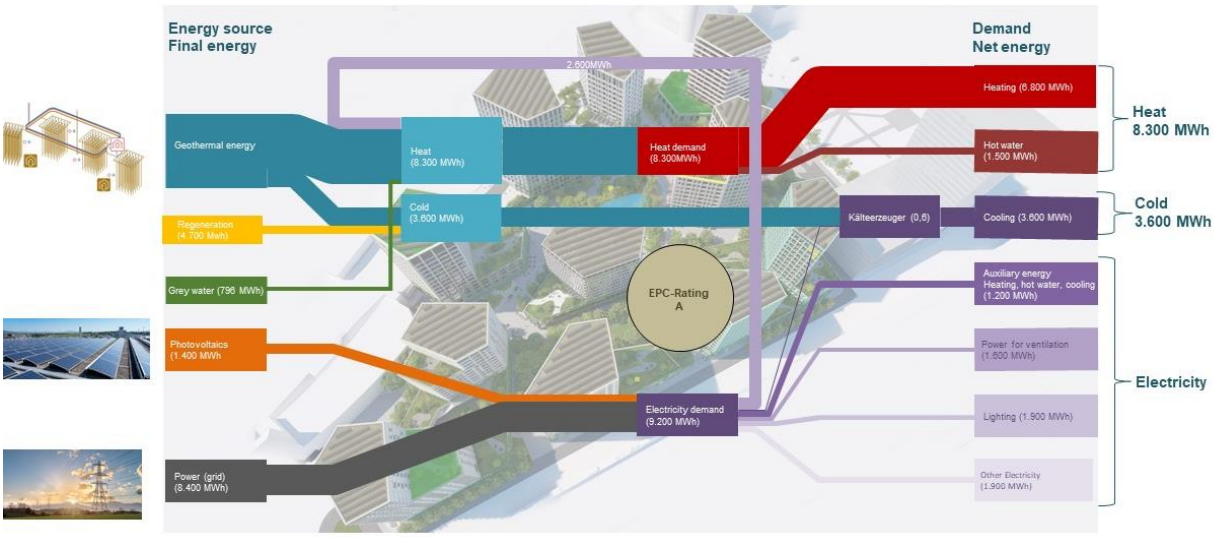

Figure 15: Sankey diagram illustrating the energy supply concept for the Post City Gardens.

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CONFERENCE TOPICS

Future District Heating and Cooling Technologies, Solutions for Energy Efficiency, Renewable Heating and Cooling.

AN OUTLOOK ON THE ADOPTION OF RENEWABLE ENERGY SOLUTIONS AT SOUTH AFRICAN BEVERAGE MANUFACTURERS

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SUMMARY

To decarbonise industry, which accounts for half of the total energy demand, renewable and sustainable energy solutions must be embraced. Not only to meet electricity requirements but, more importantly, to substitute fossil fuels used to generate process heat. This research assesses the cost-benefits of renewable and sustainable energy solutions for the South African beverage sector, representing an estimated 3020 GWh in annual energy demand, and provides a framework for the broader adoption of these technologies. A detailed evaluation of energy usage in the South African beverage sector is used to quantify the relative financial benefits and potential carbon emission reductions. For South African beverage producers, the study concludes that investments in photovoltaic and battery energy storage systems will continue to take priority, given the favourable 17–21 % Year-1 return on capital. However, given spatial and capital constraints, the judicious planning of solar thermal energy system requirements is advocated, to address the in-situ nature of process heat generation.

INTRODUCTION

As the world's energy demand continues to grow, the adoption of renewable energy needs to accelerate dramatically to mitigate carbon emissions from burning fossil fuels [1,2]. In the last decade, measurable progress has been achieved in generating electricity from solar and wind energy, notably from solar photovoltaic (PV) systems, with global generation capacity accelerating ahead of other technologies [3]. In addition to policy and incentive support, the sustained cost reductions have contributed to this growth. On a global average, the levelised cost of energy (LCOE) from onshore wind and utility-scale PV installations, at US$0.04/kWh and US$0.06/kWh, respectively, is now lower than that of new fossil fuel power plants [3] and forecasted to reach less than US$0.03/kWh by 2030 (in 2020 real terms) [4].

The industrial sector is the largest energy user globally and in South Africa, consuming approximately half of all energy demand [5,6]. While electricity is important, fossil fuels burned on-site to generate thermal energy represent two-thirds of industrial energy requirements [5,7]. For temperatures below 400 °C, steam is the most common thermal energy transfer medium for process heating. In South Africa, the beverage's energy consumption was estimated to be 3020 GWh per annum, 62% of which is from steam boiler generated process heat. The sector is of particular interest given that it is primarily consolidated and owned by international shareholders who have announced audacious reductions in carbon emissions. However, companies have been slow to reduce their carbon footprint to date.

This research focused on the cost-benefit analyses of alternative investment options. The assessments used a novel capacity and cost forecasting approach for renewable energy solutions [4] to assess immediate and future financial returns. Return on capital and space were used to compare renewable and sustainable energy investment options. Detailed model simulations for solar thermal energy systems were used to validate findings and develop more significant insights into the competitiveness of the technologies against cheap South African coal [8].

FINDINGS

For South African beverage producers, the study concludes that investments in photovoltaic and battery energy storage systems will continue to take priority, given the lower perceived risks and the 17–21% Year-1 return on capital as presented in Table 1. For high-temperature heat pumps, the availability of low-cost power (<US$0.07/kWh) and high utilisation rates are essential for projects to be viable [9]. While returns from solar thermal energy systems were acceptable against liquid fossil fuels, Year-1 return against coal were found to be low single digit. Nonetheless, given spatial and capital constraints, the judicious planning of solar thermal energy system requirements is advocated to address the in-situ nature of process heat generation.

The levelised cost of heat from solar thermal parabolic trough collectors operating in Cape Town was determined to be US$38–57/MWh$_{th}$ (2020 real US Dollar value) [8]. Currently, using the most optimistic capital cost for collectors and system integration, the cost of heat from solar thermal energy systems is at the upper end of coal-generated steam at US$20–40/MWh$_{th}$ (using contract prices of US$100–200 per tonne). With the turmoil in energy markets and large-scale installations being commissioned in Europe in 2023 [10], a tipping point is seemingly being reached. Nonetheless policy and fiscal support will be necessary to develop local capabilities and for large-scale installations to be commissioned in the short- to medium-term in South Africa.

Table 1: Comparative Year-1 return on capital

	Capex	**Year-1 cost avoided**	**Year-1 return on Capex**
	(US$)	(US$/kW)	(%)
2020			
PV vs electricity std tariffs	883 per kW$_p$	152	17%
Solar thermal energy vs coal @ US$165/t	460	40	5%
Solar thermal energy vs coal @ US$300/t	per m^2	73	10%
Heat Pump vs coal @ US$300/t	500 per kW$_{th}$	20	4%
BESS vs peak tariffs + diesel gen	430 per kWh	111 per kWh	26%

Notes: PV collector production of 5.29 kWh/kW$_p$ a day for a 670 W$_{peak}$ 3.1m^2 module[8]; Capex values are for large projects >1 MW[9,10] with projections from published analyses[4]; Electricity based on Eskom Megaflex variable tariffs @ ZAR16.50/US$[11] and increasing at 3% above inflation; Heat pump LCOH of US$45/MWh is the lowest cost from Saini et al.[6]; BESS using 1240h of peak tariff avoidance and 1000h of diesel generator avoidance with the oil price at US$70/barrel.

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CONFERENCE TOPIC

Approaches towards net-zero/negative emissions in the industry

WALK-THROUGH ENERGY AUDIT OF HOT WATER SYSTEM – A CASE STUDY OF THE UNIVERSITY OF BOTSWANA INDOOR SPORTS CENTRE

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SUMMARY

Heat loss in commercial buildings is a major challenge in the provision of hot water. The need to ensure that hot water systems installed in commercial buildings operate optimally demands that periodic performance assessments be carried out. Therefore, an energy audit for the University of Botswana Indoor Sports Centre hot water system is presented. The hot water system consists of four boilers, with a total capacity of 12.7020 kW. A walk-through audit approach was used in evaluating the performance of the hot water system and a Sankey plot was used to illustrate the outcome of the audit. The audit showed that 17% of the total energy generated is lost to the environment and poor insulation accounted for the major cause. Energy efficiency measures were recommended to improve the system's performance.

Keywords: audit, Sankey plot, energy, hot water, insulation, boilers

INTRODUCTION

Energy auditing is a process of assessing and analyzing the energy usage and efficiency of a building, facility, or industrial process. Through it, it is possible to analyze the energy balance of a system in order to define possible improvements in its energy efficiency, achieve the mitigation of its environmental impact, and reduce energy costs (Darshan, et al., 2022). An energy audit examines how much energy a household or building consumes and then develops a method to optimize energy consumption by increasing efficiency. The energy consumption purely depends on the architecture with the design and the maintenance due to the usage of the devices. Lighting and thermal play a vital role in energy consumption patterns (Dongellini, Marinosci, & Morini, 2014).

Energy auditing can be comprehensive, targeted, or preliminary (Mohamed, Fakhoury, Aldalou, & Almasri, 2022). According to Mohamed and others, (2022), applying direct comprehensive energy auditing can be too detailed, expensive, and time-consuming. Preliminary energy audits are crucial in order to identify the essential problems regarding energy consumption in the building and suggest practical solutions and this can be usually done without the need to undergo detailed energy audits. According to Dongellini and others, (2014), the various steps involved in energy auditing are completing an energy analysis of the system, identifying energy waste, defining the retrofitting plan needed to obtain a reduction of energy consumption, implementing a systematic plan for the development of energy saving projects and monitoring of the results.

A hot water system in a building is designed to supply heated water for activities such as showering, laundry, and space heating. The components of a hot water system can vary but they generally include, a water heater which is the core component of the system that heats the water, a distribution system which includes pipes that distribute heated water to various points throughout the building, temperature regulation devices or thermostats which help maintain the desired water temperature and insulation to help reduce heat losses (Kubba, 2012). During the heating process, the energy source (electricity, solar, natural gas) is used to heat the water within the water heater. The amount of energy required depends on the desired water temperature (Lee, 2004). According to Kubba, (2012), there are several losses that can be experienced on water heating systems. In storage tank water heaters, heat can be lost through the tank walls even when hot water is not being used. Insulation helps minimize these losses. As hot water travels through the pipes from the heater to the faucets, some heat may be lost due to the

temperature difference between the hot water and the surrounding environment. Energy consumption also depends on how people use hot water. Longer showers, frequent hot water use, and high-temperature settings on appliances can increase energy consumption. Efforts to reduce the energy consumption of a hot water system include using efficient water heaters, improving insulation, implementing temperature controls, and adopting water-saving practices. Also choosing the right type of water heater for a building's needs and climate conditions can significantly impact energy efficiency and cost savings (Pomianowski, Johra, Marszal-Pomianowski, & Zhang, 2020). Multipurpose buildings such as an Indoor Sports Centre generally have larger thermal loads since they are used for different purposes and sometimes even rented out for big events. As the amount of energy consumption increases it becomes a concern due to the fact that it increases the budget. The aim of this study is to undertake an audit of the hot water system in the University of Botswana (UB) Indoor Sports Centre.

METHODOLOGY

Four boilers of a total capacity of 12.7020 kW heat up water which is delivered to the showers on both the first floor and the second. The following procedure was followed in data acquisition for the walk-through audit of the UB Indoor Sports Centre hot water system. The room temperature and initial test water temperature were all measured to be 25.4°C. A 20-litre bucket was filled with hot water from the shower until full and the temperature of the water was recorded. The time taken to fill the 20-litre bucket was found to be 2 minutes and 42 seconds. The same procedure was repeated 8 times, hence a total water capacity of 160 litres. A 5-minute break was taken to allow for the pipes to cool. When the break ended the initial temperature after cooling was recorded and found to be 44°C. The testing procedure resumed, and another bucket was filled and continued with the same procedure of filling the bucket, recording the temperature, and dumping the water. This was repeated four times until the temperatures stabilized. Fig 1 shows a storage-tank water heater from the UB Indoor Sports Centre.

Fig 1: A storage tank water heater from Indoor Sports Centre

RESULTS

The Sankey plot shows that only 42.1330 kW of the energy in the water is delivered to the showers, and 8.6750 kW is lost to the surroundings which is about 17 % of the energy is lost to the surrounding.

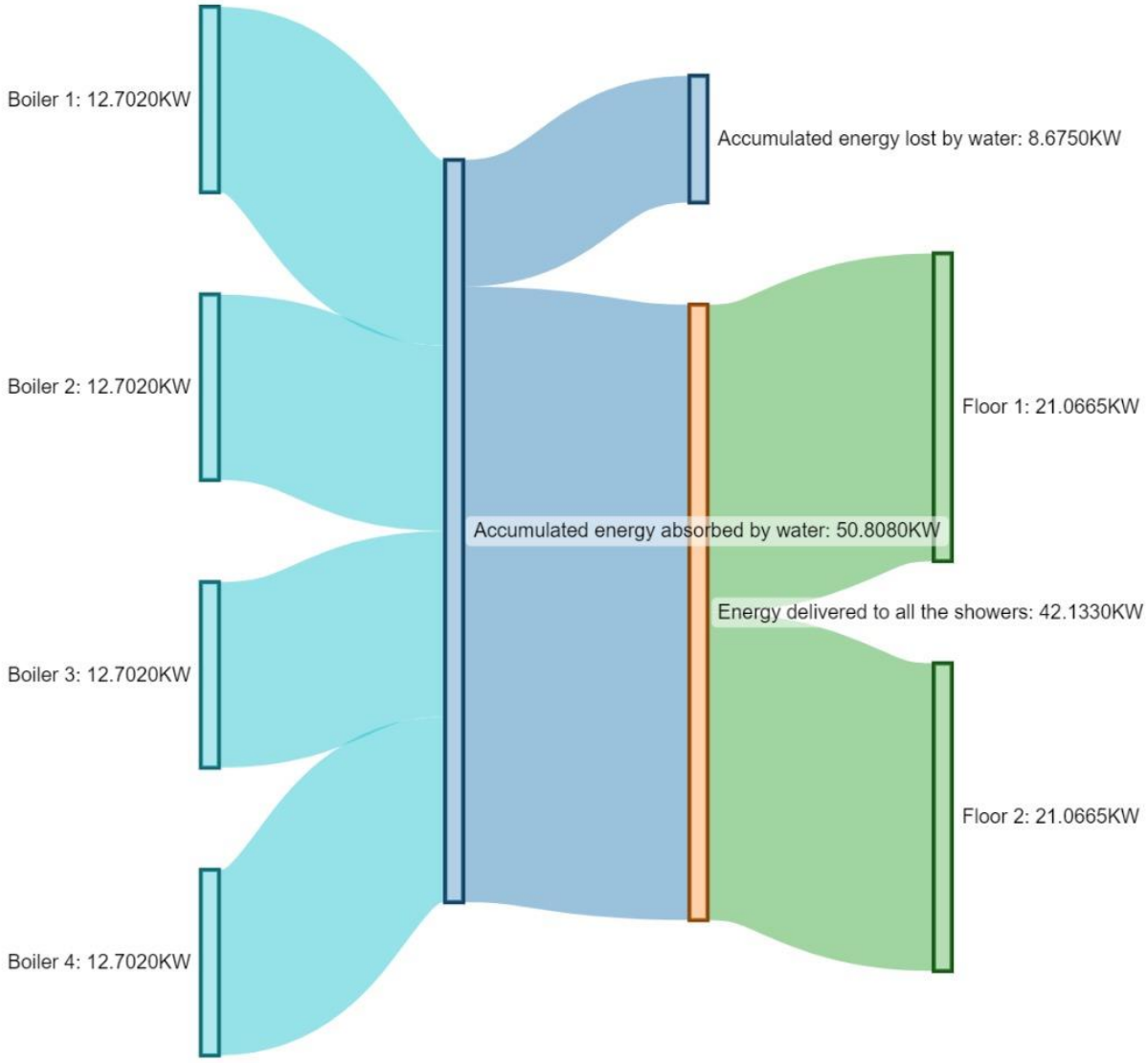

Fig. 2: Sankey plot of the energy distribution

Recommended energy efficiency measures to address these heat energy losses include to properly insulate hot water pipes that supply the showers and use of high-quality insulation materials. Another measure is the review of the routing of hot water pipes to minimize the length of the pipe runs from the water heater to the showers. Shorter pipe runs can reduce heat losses and the time it takes for hot water to reach the fixtures. Also, the installation of heat traps or check valves on the hot water lines to prevent the natural convection of hot water within the pipes will help reduce heat losses. Finally, the installation of timer-based or on-demand hot water recirculation systems to ensure hot water is available at the fixtures when needed, thereby reducing the need to run water and wait for it to heat up.

Implementation of advanced control systems that allow for better monitoring and control of hot water distribution, helping to optimize energy use and reduce waste is very helpful.

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CONFERENCE TOPIC

Solutions for Energy Efficiency

INCREASING THE PARTICIPATION OF WOMEN IN THE RHC SECTOR THROUGH SOLTRAIN+

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SUMMARY

SOLTRAIN+ [1] expands efforts of the SOLTRAIN project by incorporating industrial applications, process optimisation and energy efficiency with a dedicated 'Women in Energy' work package, The project, funded by the Austrian Development Agency (ADA) is being implemented in Botswana, Lesotho, Namibia, South Africa and Zimbabwe and focuses on training, awareness, demonstration of technologies and planning in the renewable heating and cooling (RHC) sector as a way to address climate change towards energy sovereignty (ES).

SOLTRAIN+ Gender & Diversity (G&D), aims to increase the participation of women in a male dominated sector, in line with national sustainable development goals, regional protocol and strategies.[1] A situational analysis provides structure to the implementation phase which will be presented as a series, 'Introduction' – Reasoning for including SOLTRAIN+ G&D, 'Results' – Desk top findings and results from survey of 103 people in the RHC sector, 'Implementation' – Intended areas of support to women in RHC and the structured plan.

INTRODUCTION

Part 1 – Introducing the SOLTRAIN+ Project and Gender & Diversity Work Package (Selma Festus)

SOLTRAIN+ contributes to the transformation of energy systems through the implementation of RHC technology in targeted sectors. The introduction will showcase the project focal areas and reasoning of enabling a gender-balanced community.

SADC boasts one of the highest levels of solar irradiation in the world[2] yet renewable energy solutions remain underutilised.[3] Energy is the largest contributor to carbon emissions in the region with over 50% of the total final consumption (TFC) being used for electricity, cooking, and heating & cooling.[4] In addition the region is impacted economically by the electricity supply deficit.

Research shows that women and children are the most vulnerable to the adverse effects of climate change.[5]. However, women face barriers in economic participation particularly in technical fields.[6] Female led households where the woman is the sole provider is over 35% in SOLTRAIN+ countries yet labour force participation of women and firms with majority female ownership remain low. [7]

SOLTRAIN+ G&D is seen as essential to enhance dialogue and support the access of women and young talents to the community of RHC technologies. Identifying gaps and barriers affecting the participation of women in the sector will provide concrete actions towards effective change. The vision is to build an open, creative, collaborative approach and fun environment that attracts women into working in the sector with a mission to provide a safe and engaging place to grow, test and transform ourselves and each other.

Part 2 – SOLTRAIN+ Gender & Diversity Situational Analysis & Needs Assessment Results (Monika Spork-Dur)

The situational analysis provides an understanding of the landscape for women in RHC in the SOLTRAIN+ countries. The review covered climate change, thermal sector, electricity sector, renewable energy markets and gender equality indicators. A survey of over 100 participants (80% women) in the RHC sector provided an in depth understanding of the needs of the industry to become more inclusive. The findings and results will be presented in this section.

Findings show that all five countries have developed national G&D policies, include G&D into planning and have signed international policies. Social Institutions and Gender Index (SIGI) rank (Lesotho not ranked) were low highlighting progressive shifts.[7] However, legislation and reporting systems remain weak. Wage inequality remains a challenge. Social norms provide a conducive environment for a high level of acceptance of gender-based violence (GBV) and gender role definition.[7] Participation in parliament, education attainment, labour force participation and unemployment levels of women vary.[7] Shockingly, Botswana, Lesotho, and South Africa rank in the top three countries for the highest rape rates in the world. [8]

The survey results highlighted the low level of women in the field and especially in technical positions was diverse in the countries ranging between 3% to 37% and dependent on the size of the organization. The main barriers identified were lack of awareness of opportunities, lack of mentoring and lack of training. Social norms particularly mindset change, and lack of gender targets were seen as important to increase the share of women in the sector. The preferred measures to support women in the RHC sector were equal opportunities, capacity building and mentoring networking.

Part 3 – SOLTRAIN+ G&D Implementation 2024 – 2026 (Karen Gibson)

SOLTRAIN has a history of delivering ambitious results and SOLTRAIN+ incorporates the same philosophy towards creating opportunities and awareness to increase female participation. This section combines the 'introduction' and 'needs assessment results' to present the structure and planned actions by the SOLTRAIN team with intended impact for SOLTRAIN+ Gender and Diversity over the next three years (2024 to 2026).

The five countries have overarching and specific G&D gaps and barriers to address which have been identified through the situational analysis process. The needs are aligned to provide opportunities within the budget and SOLTRAIN+ project structure in areas of awareness, dissemination and communication, training, and education, as well as access to grant funding for the implementation of RHC solutions and energy audits.

The implementation structure is tiered and creates a multi-level access to opportunities. Led by the core team, aligned with project partners, implemented by gender managers, and multiplied through a network of 'gender multipliers' which aims at creating strategic partnerships. This phase of the project should reach over 150 women and provide foundations for continued action beyond the SOLTRAIN+ project.

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CONFERENCE TOPIC

The Conference Topics this abstract refers:
'Renewable heating and cooling, including high temperature applications'.

DESIGN AND ECONOMIC ANALYSIS OF A SOLAR THERMAL PRE-COOLING SYSTEM FOR AGRO-PRODUCE COLD CHAIN IN LESOTHO

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SUMMARY

This study explores the design and economic analysis of a solar thermal pre-cooling system for agro-produce cold chain in Lesotho. The study addresses Lesotho's agricultural challenges, focusing on post-harvest losses due to insufficient pre-cooling. An economic analysis is integrated using MATLAB, and mathematical modeling and simulation using TRNSYS. Key findings highlight solar fraction, collector efficiency, exergy efficiency, energy savings, and economic performance given different coefficient of performance (COP) values. The study shows that the system is financially feasible, addressing global needs for sustainable and cost-effective cooling.

INTRODUCTION

Lesotho's agricultural sector, which supports more than 70% of the population with food and income, faces 30-40% post-harvest losses due to lack of cold storage [1]. Solar thermal pre-cooling is an ideal solution to this challenge. This study intends to assess the current refrigeration status, evaluate solar thermal potential, design an efficient system with pre-cooling temperatures of 0-12°C, and conduct an economic analysis.

Cold storage accounts for 30% of global power consumption and IRENA projects a 45% increase in cooling demand from 2016 to 2050 [2, 3]. Solar thermal cooling is a compelling solution for Lesotho due to the abundance of irradiation (5.5-7.2 kWh/m^2/day) and lack of national grid coverage [4]. It could also lead to about 40-50% primary energy savings [5].

METHODS

Absorption cooling technology was chosen for the pre-cooling system and was modeled in TRNSYS using TMY2 weather data for Maseru, Lesotho. Danfoss Cool-Selector software served to determine the desired cooling load for a 64 m^3 cold room. The collector efficiency, solar fraction, primary energy savings, exergy efficiency, and COP, were evaluated. MATLAB facilitated the economic analysis, calculating the levelized cost of energy (LCOE), net present value (NPV) and discounted payback period (DPP), with a discount rate of 7.75% assumed over a 20-year system lifetime. The consideration of costs, energy savings and Lesotho's electricity tariff rate translates into tangible financial returns.

RESULTS AND DISCUSSIONS

With the cooling load of 7.318 kW, the solar fraction of 1 was achieved with a COP of 0.8, representing full system reliance on solar energy. Larger collector areas up to 24 m^2 enhanced solar fraction. The collector efficiency peaked at a 30° slope, aligning with Maseru's latitude and allowing optimal collector performance. The primary energy savings increased with the collector area and COP, indicating a positive impact on energy savings. Higher COP values resulted in greater energy savings and reduced auxiliary energy requirements. Exergy efficiency also improved with higher COP values, signifying more effective energy conversion and overall system performance.

The economic impact analysis revealed that LCOE decreased with higher COP values, reaching $0.085/kWh, which signaled cost-effectiveness. NPV emphasized the financial feasibility of higher COP systems, with optimal performance at COP of 0.8 giving NPV of $9,200 and 12 years DPP.

The optimal system parameters include COP of 0.8, a collector area of 12 m^2, and a hot storage volume of 0.5 m^3. This choice maximizes solar energy utilization, enhances energy efficiency, and ensures economic viability, making it a compelling option for sustainable refrigeration in the region.

CONCLUSIONS AND RECOMMENDATIONS

Critical metrics, such as LCOE and NPV affirm the system's financial feasibility for Lesotho's refrigeration needs. The short DPP (12 years) and early break-even on year 13 enhance its appeal, showcasing its potential impact on sustainable refrigeration. However, the study is limited to technical and economic aspects, omitting parasitic electrical energy consumers. Acknowledging this limitation suggests areas for refinement in future research.

While this study constructs a compelling case for the adoption of solar thermal pre-cooling, future studies could explore advanced optimization through machine learning, dynamic models for heightened reliability, and comprehensive analyses of market dynamics and policy frameworks. Real-world implementation and monitoring stand out as imperative for validation. Additionally, long-term financing and hybrid system integration could further enhance affordability.

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CONFERENCE TOPIC

Renewable heating and cooling

LIFE CYCLE ASSESSMENT OF THERMOSYPHON AND PV HOT WATER SYSTEMS UNDER THE SAME OPERATING CONDITIONS IN A SIDE-BY-SIDE EXPERIMENTAL SETUP IN NAMIBIA: INITIAL RESULTS AND DATA COMPARISON WITH EXISTING SIMILAR INSTALLATIONS

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SUMMARY

The global demand for hot water is increasing, driving a shift towards solar technologies. Namibia, aligning with emission reduction goals, plans to replace electric boilers with solar thermal and PV2Heat systems, emphasizing cost efficiency. This study focuses on providing eco-performance data for solar hot water systems, specifically thermosiphon and PV systems. Three systems in a container at the NUST Science and Technology Park are being compared, with commissioning scheduled for 2024. Preliminary eco-performance data will be derived from initial monitoring, followed by a comprehensive life cycle assessment (LCA). The study envisions a straightforward process in generating input data for the LCA, including performance data. Determining the levelized cost of electricity (LCOE) for economic comparison is a key aspect. While leveraging existing data from previous works, it acknowledges the limitations in estimating expected eco-performance indicators. The study aims for a direct LCA and eco-performance comparison between solar thermal and photovoltaic-based systems, contributing to Namibia's sustainable energy strategy.

INTRODUCTION

The demand for hot water is increasing worldwide. Many countries have set targets to promote a higher proportion of energy production through solar technologies. A global energy strategy is crucial to meet the growing energy demand, minimize the environmental impact and reduce dependence on fossil fuels. The use of solar thermal energy for water heating is a promising and sustainable option. Two technologies are particularly promising for the so-called Sunbelt region (between the 20th and 40th parallel in the northern and southern hemisphere), where Namibia is located (Weiss and Spörk-Dür 2023). These technologies are solar thermal thermosiphon systems and electric hot water systems powered by photovoltaics (PV2Heat). They are expected to play the largest role in the solar hot water market in this region in 2030.

Namibia is focusing strongly on reducing its greenhouse gas emissions in line with its Intended Nationally Determined Contributions (NDCs) to mitigate climate change. The reduction potential for 2030 is estimated at up to 91 % (Republic of Namibia 2021).

The strategy for achieving the target in the energy sector is to replace conventional electric boilers with the above-mentioned solar thermal systems and PV2Heat systems with a particular focus on cost efficiency for the sustainable use of these systems for the end consumer.

The aim of the present work is to accompany this strategy with eco-performance indicators, as to date there is hardly any meaningful data, literature and comprehensive comparative studies on thermosiphon and PV hot water systems for household applications under real environmental conditions, especially for Namibia.

EXPERIMENTAL & MODELLING

In the comparative study mentioned in the introduction, which serves as the basis for the life cycle assessment, 3 different hot water systems are examined.
They each consist of a 200-liter tank and collectors/PV modules with 1.2-1.6 kW equivalent rated thermal output/kW peak:

- System 1: Indirect thermosyphon system with a flat-plate collector;
- System 2: Indirect thermosyphon system with evacuated heat pipe collector and
- System 3: PV-to-heat (PV2Heat) system.

The overall aim of the systems under investigation is to carry out a direct comparison of small systems for solar hot water generation, including energy monitoring and determination of the heat generation costs. The three systems are installed in a 12 m long shipping container, with the monitoring system, the controls and the storage tank of the PV2Heat system housed in the container. Figure 1 illustrates the structure of the container. The container will be installed in the NUST Science and Technology Park.

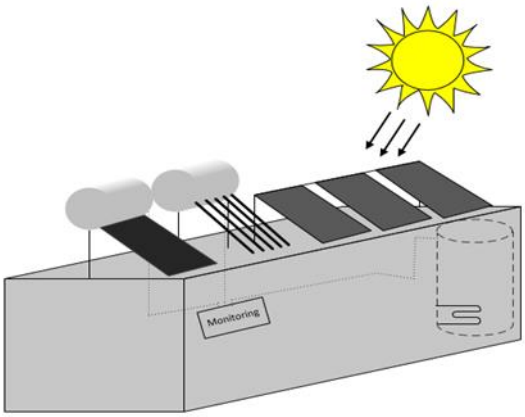

Fig. 1: Experimental setup of the side-by-side comparison of thermosyphon and PV hot water systems

The project is currently in the detailed planning phase and the first components are being shipped to the site. Commissioning of the plant is planned for the beginning of 2024. The technical details will be presented in a separate paper.
The life cycle assessment parameters will be determined on the basis of the detailed planning and, if sufficient initial monitoring data is available, preliminary eco-performance data will also be derived.
As the monitoring phase of the project extends beyond the period of this study, comparative data from previous studies (Buckley et al. 2019; Shimhanda et al. 2018; Kicker et al. 2017; Kicker et al. 2018a, 2019; Kicker et al. 2018b) will also be used to create a preliminary comparative database and to estimate the expected eco-performance indicators.
A comprehensive and final life cycle assessment and determination of the eco-performance indicators is planned in a follow-up study after the monitoring phase has been completed.

RESULTS AND DISCUSSION

For the preparation of the LCA, it is expected that the generation of the associated input data, such as the performance data for the derivation of the eco-performance data, which are obtained by monitoring the metrological data and the technical data of the system, will not present any hurdles.
Based on the costs for the components of the system, the LCOE can be determined, which can serve as an economic indicator for the comparison and also flow into a detailed economic and ecological performance data generation derived from the life cycle analysis (LCA) of the system.

As the current work cannot take into account the entire monitoring period, existing data from previous work on similar systems is also used.
However, as the previous work lacks an absolute basis for comparison, as is the case in the current project, and no data is available for all three hot water systems currently being investigated, these generated parameters only represent an initial basis for estimating the expected eco-performance indicators.
An important finding of this work and the planned follow-up work after completion of the entire monitoring phase will be the direct comparison of the LCA and eco-performance indicators from the two solar thermal systems in direct comparison with the hot water system based on photovoltaic

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Renewable heating and cooling, including high temperature applications
- Life Cycle Assessment
- Special focus on developing countries

A NOVEL MODULAR SORBER REACTOR FOR LOW-GRADE THERMAL ENERGY STORAGE

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SUMMARY

One of the main challenges of the existing sorption heat transformers and thermal storage systems is their thermal inertia. To address this issue, a new shell and tube reactor design is proposed that offer a much larger active mass, e.g., lower mass ratio (mass of the system to mass of the active materials). Characterization analyses such as thermal conductivity/diffusivity measurement, thermogravimetriy and porosimetry analyses are conducted for the new sorption composite and the reactor proposed in this study. Using the analysis and the characterization data, a new sorber reactor is fabricated and tested in our lab accordingly. Calorimetric tests on the proposed modular sorber reactor shows a promising 0.85 MJ/kg energy storage density and specific power of 405 (W/kg) for the module under operating conditions of 90°C, 30°C, 30°C, 15°C, desorption, sorption, condenser, evaporator, respectively.

Keywords: Thermal energy storage; sorption heat transformers, low-grade waste heat; district heating

INTRODUCTION

Sorption heat storage systems are gaining popularity since they have the potential to mitigate global climate change issues, cut fossil fuel usage, and make better use of renewable and waste energy [1]. The adsorber bed is the main part of sorption heat transformer systems and has a significant impact on the system's performance and cost. Therefore, significant research has been focused on this component in recent years [2]–[4]. It is necessary to have an in-depth understanding of sorption dynamic, heat and mass transfer phenomena, as well as mass ratio and manufacturing costs in such reactors.

In this study, a new design for sorber reactors is proposed that eliminates the need for a thick vacuum chamber [5]. The proposed shell and tube reactor design consists of ultra-thin tubes attached to a tube sheet with a specific arrangement, shown in Fig. 1. New functional sorbent composites are also fabricated and installed inside the tubes in shapes of hollow cylindrical discs. The heat transfer fluid flows inside the shell side that is equipped with baffles to enhance heat transfer.

PRELIMINARY RESULTS

To characterize the performance of this sorber bed, a custom-built sorption test set up was developed in our lab, Fig. 2. Temperature of the evaporator can be adjusted by a water circulator to cover different sorption conditions and the reactor temperature was fixed at 30°C using another water circulator.

Figure 1. Proposed modular reactor.

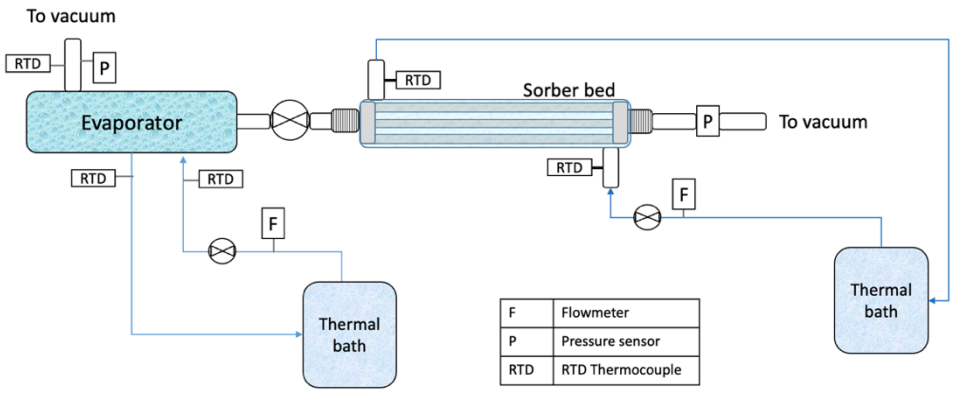

Figure 2. Schematic of the custom-built sorption thermal energy storage test setup.

The new sorbent composites used in the reactor were a salt in porous matrix, consisting of 52 wt.% silica gel, 35 wt.% calcium chloride, 6 wt.% expanded natural graphite, and 7 wt.% polyvinyle alcohol. Sorbents were made in hollow disc shape particles with a thickness of 5 mm. Their thermal conductivity and thermal diffusivity were measured using a TPS in our lab of about 0.38 W/m.K and 1.2×10^{-6} m/s^2, respectively; refer to Ref. [6] for more details on TPS measurements.

Table 1 shows the results for key performance indicators from preliminary test results under operating conditions of 90°C, 30°C, 30°C, 15°C, desorption, sorption, condenser, evaporator, respectively.

Table 1. Key performance indicators (KPIs) for modular sorber bed

KPIs	Definition	Value
Energy storage density	$Q_{adsorption}/m_{sorbent}$	0.85[MJ/kg]
Specific Power	$dQ_{adsorption}/dt.m_{sorbent}$	405[W/kg]
Coefficient of performance	$Q_{adsorption}/(Q_{desorption} + Q_{sensible})$	0.73(COP)
Mass ratio	$m_{system}/ m_{sorbent}$	5.31

ACKNOLWEGEMENT

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THERMOCHEMICAL HEAT STORAGE BY HIGH PERFORMANCE SALT AMMONIATES

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SUMMARY

Merging the expertise in coordination chemistry, thermochemical energy storage materials and microfluidic reactor design yields a novel approach to a modular waste heat and recovery storage device, i.e. a thermochemical heat battery. Based on the synthetic chemical knowledge on transition metal chemistry we investigated salt ammoniates in recent years. To overcome the intrinsic problem of drastic volume work upon ammoniation of anhydrous copper sulphate we miniaturized the system achieving a unique surface-to-volume ratio in µg-scale and embedded and suspended the copper sulphate in a polymer matrix. After proof-of-principle we optimize the microfluidic chip design to develop a modular device, which can be stacked into chip packs thus representing a novel thermochemical energy storage system working as rechargeable heat battery.

key-words: thermochemical energy storage materials (TCM), salt ammoniates, micro-reactor array

INTRODUCTION

Thermochemical energy storage materials (TCM) yields the highest heat storage capacities in comparison to the use of phase change materials (PCM) or sensible heat storage. TCMs usually represent a pair of solid compounds *A* and *AB* reacting reversible with a gaseous compound *B* storing and releasing heat ΔH (see equation 1).

$$A + B \rightleftharpoons AB + \Delta H \qquad \text{(eq. 1)}$$

In recent years we focused on anhydrous transition metal salts as solid compound *A* and ammonia as gaseous compound *B* yielding ammoniated salts *AB* [1]. As metal halides are volatile at elevated temperatures their cycle stability is deteriorating over time. Hence, we stick to the non-volatile copper sulphate as best performing transition metal salt with respect to its energy storage capacity. However, we encountered a drastic volume change of the copper sulphate upon ammoniation towards the 2.6-fold volume (see Figure 1). Therefore, we circumvented this problem by using zeolite 13X as support material [2].

Figure 1. Volumetric expansion of $CuSO_4$ during reaction with NH_3, resulting $[Cu(NH_3)_4]SO_4$ in the case of (**a**) pure $CuSO_4$, (**b**) $CuSO_4$ on sepiolite 10:1 wt. % and (**c**) CuNaX zeolite. For the zeolite sample the color change during reaction with NH_3 towards the darker color of $[Cu(NH_3)_4]SO_4$ is hardly visible.

With this approach we could solve the problem of the volume work upon ammoniation/deammoniation, but decr4eased the volumetric or gravimetric energy storage capacity drastically.

RESULTS

This led us to a completely new approach combining the advantages of miniaturization (increasing the surface – to – volume ratio) via lab-on-a-chip technology with the modularization allowing to stack several chips into packs and thus upscale the devices to a thermochemical heat storage battery, which can be tuned to the heat supply and demand of individual user cases. Based on preliminary work [3] preparing a chip prototype and proofing the concept, we filed a patent [4] and applied for funding to develop a lab-size prototype. The general concept is depicted in Figure 2. First results of the prototype performance will be reported.

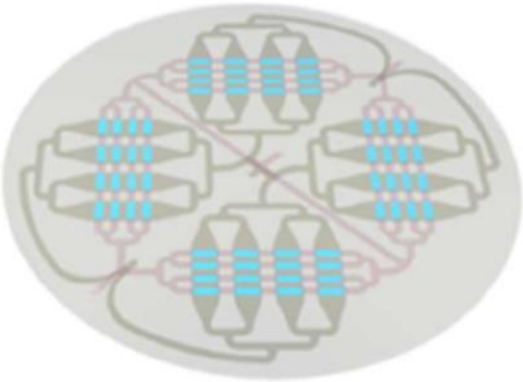

Figure 2: Graphical representation of the microfluidic reactor array showing the reaction chambers with the embedded copper sulphate (blue) interconnected with microfluidic gas channels for the ammonia and in a separate perpendicular layer the heat transfer fluid (thermooil).

ACKNOWLEDGMENTS

Financial support of aws Prototypenförderung für Universitäten und Fachhochschulen, project P2409836 (Microfluidic Thermochemical Energy Storage Microreactor Array) is gratefully acknowledged.

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CONFERENCE TOPIC

Emerging heat and cold storage

TESTING AND ANALYSIS OF A DUAL-TUBE LATENT HEAT STORAGE SYSTEM

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SUMMARY

In order to effectively charge and discharge a latent heat thermal energy storage (LH-TES), a driving temperature difference between charging and discharging needs to exist, resulting in a higher charging than discharging temperature. A dual-tube LH-TES concept was developed in order to make this possible using different media or process parameters in separated tubes without the need for expensive valves and control systems. A storage unit was designed, tested and built using two different refrigerants in the respective charging and discharging processes, showing the feasibility of such a system. An axially finned tube was designed to be assembled on tube-pairs, allowing for heat conduction via highly conductive aluminum directly between the circuits, as well as heat transfer between the heat transfer fluid and the phase change storage material. Data from the experimental analysis will be shown and discussed.

INTRODUCTION

The LH-TES tested here was designed for the coupling of a high-temperature heat pump and an organic Rankine cycle in order to create a flexible energy management system, as discussed in [Wel]. The heat pump upgrades heat, thereby evaporating the refrigerant. This condenses in the LH-TES, thereby charging the storage. When energy is dispatched again, the other refrigerant is pumped through the LH-TES, evaporating and discharging it. This is then condensed in the organic Rankine cycle while converting a portion of the thermal energy to electricity. The coupling of these systems required not only the driving temperature difference between the charging and discharging cycles in the LH-TES, but also differing refrigerants as well as lubricants for the heat pump and organic Rankine cycle machines. To this end, this storage concept was developed, built and tested. The analyses of the LH-TES are shown here.

The LH-TES unit is designed as a vertical shell and tube heat exchanger embedded in the phase change material (PCM) consisting of a nitrate salts mixture. This allows for condensation and evaporation of the working fluids in the tubes at small temperature differences with respect to the melting temperature of the PCM on the shell side in order to minimize entropy generation in the system. Hence the heat transfer efficiency between the PCM and working fluid is maximized.

Axial aluminum fins connect the two tube systems and are immersed in the PCM storage media. These improve the heat transfer between the PCM and the working fluid in the heat exchanger tubes, since nitrate salts generally have a low thermal conductivity of about 0.5 W/m/K [Meh]. In the desired temperature range, aluminum is a suitable fin material due to its high thermal conductivity (210 W/m/K) and formability. Figure 16 shows a dual tube assembly consisting of two fin segments and two steel tubes on the left and the storage integrated into the lab in the middle. The design parameters of the unit are summarized in Table 1.

Figure 16 on the right**Fehler! Verweisquelle konnte nicht gefunden werden.** shows the discharging and charging of the unit using thermocouple measurements around a central tube over the height of the storage, showing the melting and solidification fronts through the cycle portions and the differences in solidification and melting plateau during phase change.

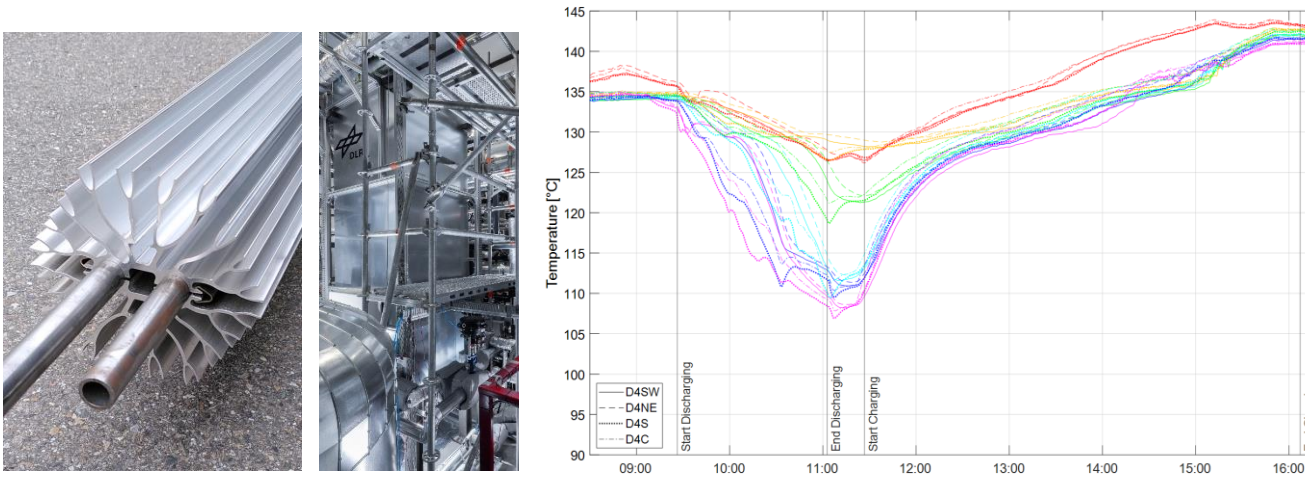

Figure 16: Dual tube assembly (left) and latent heat storage integrated into the lab (middle) and temperature distribution of the thermocouple measurements at different positions around a central tube-pair at the measurement levels 1/top to 6/bottom in red, orange, green, turquoise, blue and purple during a discharging and charging cycle (right).

Table 1: As-built design parameters of the dual-tube latent heat storage

Property	**Quantity**
Storage capacity	approx. 160 kWh
Heat exchanger type	Tube bundle with separate circuits for charging and discharging
Heat exchanger configuration	Vertical tube pairs integrated in PCM volume and connected to headers
Effective tube length	3 m
Storage material (PCM)	Eutectic of KNO_3 - $LiNO_3$ (67 wt% - 33 wt%), melting temperature 133 °C
PCM mass	approx. 4400 kg

CONCLUSIONS

This set of results as well as further experiments show the feasibility of the dual-tube design, allowing for coupling of systems with a minimization of necessary driving temperature difference. The dual-tube design can be developed further for the flexible energy management system developed here as well as for coupling separate processes in industrial processes.

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CONFERENCE TOPIC

Emerging heat and cold storage

POTENTIAL AND CHALLENGES OF LARGE THERMAL ENERGY STORAGES

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SUMMARY

Large thermal energy storages offer more flexibility in DH Systems, also adding operational flexibility to power plants and industrial processes. Furthermore, they enable a higher share of renewables and waste heat and they can provide peak shaving functionality for electricity grids through Power-to-Heat (P2H) thus enabling sector coupling of the power and heating sector.

The market for large thermal energy storages is growing, with new plants built and planned in Denmark and Germany, mostly PTES with volumes in the range of 400,000 to 500,000 m³ (in Denmark). In order to facilitate and accelerate the market uptake of these large storages, better materials and knowledge is needed to improve the service lifetime of storages, better tools are needed for designing, planning and integrating the storages and more knowledge of the potential and integration possibilities of these storages is needed for decision makers.

WORKING TOWARDS IMPROVED LTES

The Task39 of the IEA Energy Storage Technology Collaboration Program is a three-year, international collaboration of experts in the field of large thermal energy storage and district heating. The Task aims at determining the aspects that are important in planning, design, decision-making and realising very large thermal energy storages for integration into district heating systems and for industrial processes, given the boundary conditions for different locations and different system configurations.

The key objectives are:

- Definition of a number of representative application scenarios, the connected boundary conditions and Key Performance Indicators
- Improve LTES materials and materials performance measurement methods
- Prepare guidelines for obtaining proper water quality
- Compare the performance and accuracy of simulation models for LTES
- Derive validation tests for LTES simulation models
- Generate information packages for decision makers and actively disseminate the information

The scope is determined by both technological and non-technological aspects. 4 Types of storages are considered: Pit Thermal Energy Storages (PTES), Tank Thermal Energy Storage (TTES), Aquifer Thermal Energy Storages (ATES) and Borehole Thermal Energy Storages (BTES). Water is the storage medium with atmospheric pressure (or slightly overpressure) in PTES, TTES and ATES, while soil is the storage medium in BTES.

STRUCTURE OF THE WORK

The work is subdivided into 4 Subtasks. Subtask A works on application scenarios, Key Performance Indicators (KPI) definition, the assessment of storage concepts in the scenarios and the detailing of integration aspects. Subtask B aims at composing a database of materials needed for a LTES, specifying those materials that meet the off-standard conditions of a LTES. Subtask C is dedicated to a round robin of the numerical simulation of LTES storages with real case data sets and Subtask D has as goal to develop and distribute information packages

for decision makers. Figure 1 gives an overview of the Task39 work structure and the information flow between the different Subtasks.

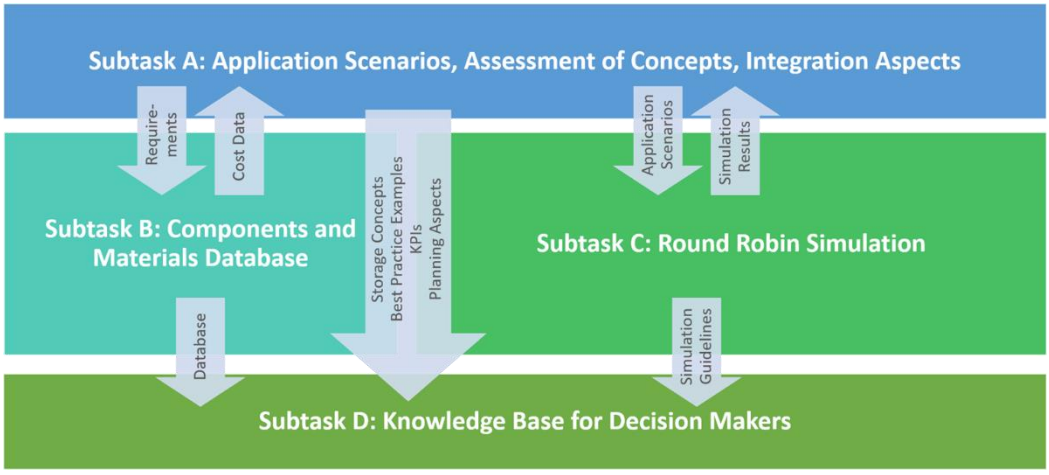

Figure 1: Schematic representation of the Annex breakdown into Work Packages and the information flow between the Work Packages

FINDINGS AND RECOMMENDATIONS

A list of Key Performance Indicators have been set up and have been determined for a number of LTES configurations. A description of LTES cases has been made, with typical challenges occurring in different topics: land use, compliance to urban rules, permitting, economical/financial and contractual schemes. With regard to materials for LTES, a database structure has been set up and first data of materials have been added. A challenge is to find and determine methods of reliably testing the material properties beyond the usual temperature range. For instance, the lifetime estimation of polymer liners for pit thermal energy storages can only be determined with accelerated test methods, which need to be validated. As the present liners are less than 10 years old and their numbers are still below statically meaningful quantities, this is still not fully possible.

A major achievement was made in the comparison of different numerical simulation models for a number of LTES technologies. For seven different technology configurations, 40 institutes from 7 countries made calculations of a seasonal performance with a strongly simplified charging and discharging pattern. The results were compared and led to some adaptations in the assumed boundary conditions of the calculations. In the follow-up Task, the calculations will be refined by using a more realistic charging and discharging pattern, with stronger dynamics in the system.

An important part of the work was to inform the different stakeholders, from planners, engineers and builders to energy service companies, district heating companies, municipalities and decision makers. Leaflets introducing the LTES technologies and typical application cases were made, presentations given to specialists and a wider audience and a policy workshop was held, in which market, legal and permitting aspects of introducing LTES to the markets were discussed.

The work in Task39 led, amongst others, to the following recommendations: fast and simple (pre)design tools to determine the performance of LTES systems in an early stage and with a minimum of input data are needed; and the complete realisation process from first idea to implementation of an LTES needs to be shortened through the development of a standardised approach, leading ultimately to performance guarantees.

CONFERENCE TOPIC

Flexibility and Stability of Thermal and Electric Grids

LARGE-SCALE UNDERGROUND THERMAL ENERGY STORAGES – AN INSIGHT INTO MATERIAL AND COMPONENT DEVELOPMENT AND TRANSITION INTO PRACTICE

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SUMMARY

Large-scale underground thermal energy storages (LTES) will occupy a decisive role in future district heating systems due to their comparatively low investment costs especially with large scale underground tank (TTES) and pit (PTES) thermal energy storages. Nevertheless, these structures with special requirements on its component units and materials pose major challenges. Currently there is a particular lack of feasible, affordable technologies, materials and construction methods due to the challenging boundary conditions in Austria and Central Europe as well as the comparatively difficult requirements associated with the application of water as a storage medium instead of, for example, gravel-water mixtures. This presentation examines the structural and material challenges and presents innovative construction concepts as well as new test methods for components and materials and serve for prospective standardization programs of large-scale underground thermal energy storages.

INTRODUCTION

TTES and PTES integrated into district heating networks enable short-, mid-therm and seasonal storage of volatile energy sources (e.g. solar thermal, wind and PV), a flexible storage of waste heat as well as the coupling of the electricity and heating sectors through power-to-heat solutions. Due to their promising cost potentials in construction and operation, large-scale underground thermal energy storages will be a key technology for a system-based and cost effective decarbonisation of future district heating systems.

APPROACH

Based on the requirements of national and international district heating systems, TTES and PTES will be designed with storage volumes (storage medium water) up to the „million cubic meter scale“. Despite the high potential, however, there is a lack of feasible, affordable technologies, materials, and construction methods due to the challenging boundary conditions in Austria and Central Europe, as well as a lack of guidelines and standardization. For example, the urban integration of these structures requires minimal land use, utilization of the storage surface, and aesthetic integration into cityscapes and landscapes. In addition, high storage temperatures of up to 99°C and dynamic loads caused by storage operation have a challenging effect on materials (e.g. liner material) and component units (e.g. wall systems). Based on this knowledge, improved material developments, test methods and economic evaluations of the new developments were carried out.

RESULTS

The presentation focusses on different aspects for a successful establishment of large-scale underground thermal energy storages in Austria. It provides an insight into material and component development (see Figure 17 and Figure 18) as well as methods and results of feasibility studies for the realisation of LTES for site-specific challenges and framework conditions.
Innovative structural concepts which have been developed based on the newly developed materials are presented. Novel component designs are discussed and evaluated in terms of structural economics. Furthermore, the

requirements for the subsequent development and transfer to possible mass or series production of materials and components will be presented, which is seen as an essential step to increase the technology readiness level and ultimately allow an upscaling to real scale.

FIGURES

Figure 17: High-performance concrete test specimens for LTES after the compressive strength test (©VÖZ)

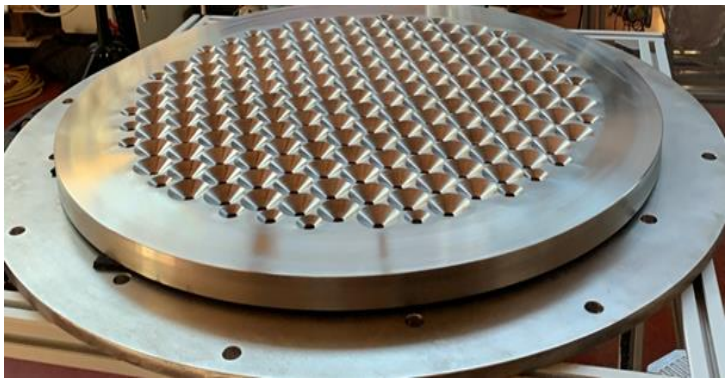

Figure 18: Components from a test apparatus for material testing (©AEE INTEC)

CONFERENCE TOPIC

Emerging Heat and Cold Storages

SOLAR HEAT FOR INDUSTRIAL PROCESSES

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SUMMARY

One result out of the joint Task 64 of the IEA Solar Heating and Cooling Technology Collaboration Programme (SHC TCP) and Task IV of the IEA Solar Power and Chemical Energy Systems Technology Collaboration Programme (SolarPACES TCP) is a technology position paper, published at:
https://task64.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task64-Technology-Position-Paper-SHIP-2024-01.pdf, (DOI: 10.18777/ieashc-task64-2024-0001).
It explains the relevance, present status and potential of the development and market of Solar Heat for Industrial Processes (SHIP), leading to actions needed to further and best exploitation. It addresses policy and decision-makers as well as influencers and aims to present high-level information as a basis for the uptake and further development of SHIP.

INTRODUCTION

Solar Heat for Industrial Processes (SHIP) has enormous potential in industrial decarbonization, addressing the industrial sector's total final low and medium temperature heat consumption that corresponds to 12% of the total final energy demand worldwide. The major share of the energy needed in this sector is used for heating and cooling production processes at temperatures up to 400 °C and is almost exclusively provided with fossil fuels, as shown in Figure 1. SHIP technologies are market-ready to significantly reduce CO_2 emissions in these applications using non-concentrating solar thermal collectors (up to 150 °C) and concentrating collectors (up to 400 °C). Solar applications for even higher temperatures are under development but not the subject of this paper.

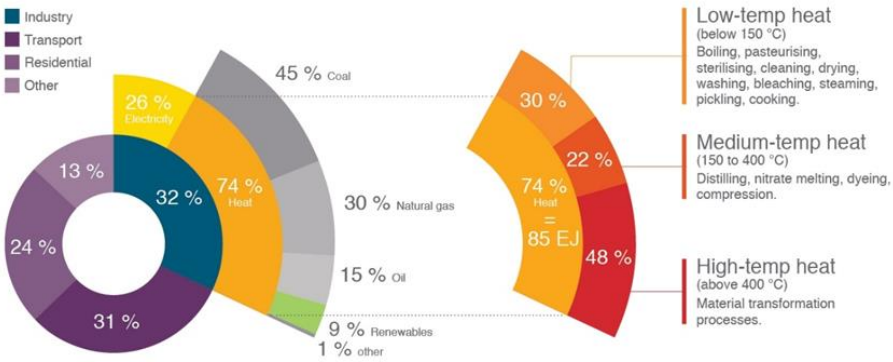

Figure 1: Total final energy demand, share of heat demand, temperature levels, and current energy carriers for industry worldwide.[1]

[1] Source: https://www.solar-payback.com

CURRENT STATUS

Around 70 turnkey providers worldwide plan, install, and operate SHIP systems acting on a strong and reliable supply chain. An increasing number of SHIP technology suppliers provide heat delivery contracts. In these models, specialized "Energy Service Companies" (ESCO) offer solar heat solutions and services to industrial clients, including designing, installing, financing, operating, and maintaining energy-efficient technologies and selling the heat at a fixed price for a specified contract period.
The paper gives further details about the present SHIP market development.

POTENTIAL

The total process heat demand worldwide was about 46,000 TWh in 2021[2]. Applying the parameter for the potential studies of IEA SHC Task 49 (Irradiation of 1,200 kWh/(m²a), 40 % annual efficiency), a conservative potential for the SHIP share of at least 4 % or 1,850 TWh is calculated. This is equivalent to a solar thermal collector potential of more than 3,900 million m² (2,730 GW) or investments of 1,900 billion €. Compared to the current market situation of around 30 MW/a installed SHIP capacity per year, SHIP's potential is almost untapped.
The paper goes into more detail on the technical and economic potential and further discusses industrial heat load profiles, cost reduction potential and the role of SHIP as part of decarbonization strategies.

ACTIONS NEEDED

In many discussions at experts' meetings the authors have identified the following challenges to strengthen the market uptake of solar heat for industrial processes:

- Economic framework
- Public awareness
- Capacity building
- Planning tools
- Modularity and design standardization
- Solutions for hybrid heat systems
- Quality infrastructure
- Cutting costs

The paper suggests actions to address these challenges.

[2] IRENA (2020) Renewable Power Generation Costs in 2020

OPERATING EXPERIENCE OF THE LARGEST GROUND-MOUNTED SOLAR PLANT IN AUSTRIA FEEDING INTO DH MÜRZZUSCHLAG

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SUMMARY

Austria's largest ground-mounted solar thermal plant was constructed in two phases, in 2020 and 2023. Based on the operating experience of the first phase, the expansion was optimally adapted to the district heating system. The monitoring shows the combined operation of biomass and high solar fractions in summer, but also potentials for improvement. An ongoing research project will implement a new control system that enables the optimal interoperation of solar thermal energy, biomass and storage in the grid, thus reducing the demand for fossil energy to a minimum.

MÜRZZUSCHLAG - LARGEST GROUND-MOUNTED SOLAR THERMAL PLANT IN AUSTRIA

In the district heating supply in Mürzzuschlag, Austria, solutions for the optimal combination of different decentralized renewable sources are developed. In 2020, a solar plant with a capacity of 3.5 MW (5,000 m²) was integrated into the district heating network in Mürzzuschlag, Austria.

Figure 19 Largest ground-mounted solar thermal plant in Austria for district heating in Mürzzuschlag

In 2023, an expansion of another 2,000 m² to a total of 4.9 MW was implemented (Figure 19). Energy storage is used to distribute the solar energy throughout the day. The integration of this solar plant confronts the grid operator with new challenges in coordinating its producers. At the same time, the storage offers new opportunities. The grid is supplied by seven producers from five locations. To achieve the goal of completely substituting fossil fuels, the implementation of additional distributed storage and additional renewable sources is being evaluated.

MONITORING AND OPERATION EXPERIENCES

The monitoring results were used for two main purposes. First, the information was incorporated into the simulations to improve results and design accuracy for the plants extension. The second purpose was to optimize the operation of the solar plant itself and the entire system. In this regard, a large amount of sensor data was recorded, processed and analysed. Two research projects

Exemplary the measured data in Figure 20 show that with 5,000m², on individual days up to 80% of the energy demand can be covered by the solar system. With the expansion to 7,000m² of solar area, individual summer days are supplied to 100%. In the whole summer, the share rises to a little over 50%. In Mürzzuschlag, this corresponds to an annual share of solar energy in the total grid demand of just under 10%.

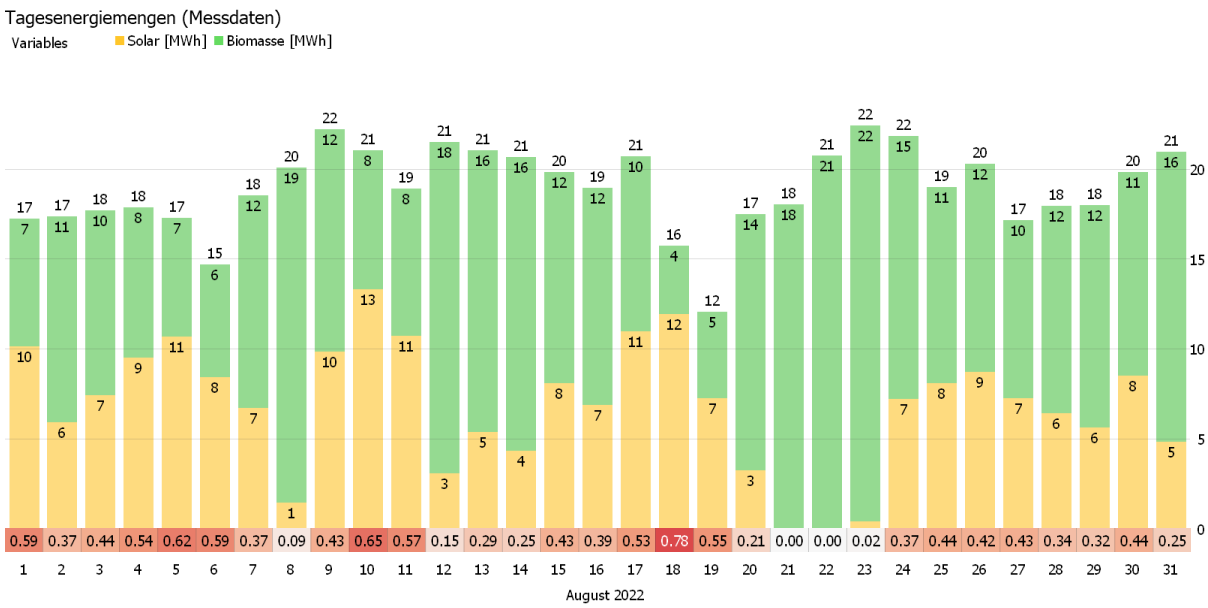

Figure 20 Summer operation Aug 2022 Solar and biomass energy quantities per day and solar fraction (0-78%)

The storage capacity of the 420 m³ heat storage tanks corresponds to the daily thermal demand during the summer. This is not only used to store solar energy during summer months but can also be used throughout the year for peak load management. Instead of gas, energy from solar and biomass sources can be used. Decentralized distributed storage not only helps to increase the amount of renewable energy, but also compensates for hydraulic and temperature-related bottlenecks.

In two research projects, simulation analyses for the goal of covering the demand with renewable energies are carried out. A new control system is to be implemented that optimally coordinates solar thermal energy, biomass and storage.

CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:
Renewable heating and cooling; Digitalization for Future Energy Systems

SUNPEEK - OPEN-SOURCE SOFTWARE FOR ISO 24194 PERFORMANCE ASSESSMENT AND MONITORING OF LARGE SOLAR THERMAL PLANTS

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SUMMARY

ISO standard 24194:2022 [1] introduces the Performance Check, a method to evaluate the operational performance of solar thermal plants using measurement data. This method targets large solar thermal plants, a) to monitor ongoing plant operation, and b) to check a performance guarantee, e.g., at plant commissioning. However, the practical use of the Performance Check is limited in that it is a mere description on paper, limiting its straightforward application by plant designers, or operators. This work introduces SunPeek, an open-source software that offers a reference implementation of the ISO 24194 Thermal Power Check and is available to all interested parties, allowing commercial use. SunPeek contains a transparent implementation of the ISO 24194 Performance Check and aims at making it practically applicable. Within IEA SHC Task 68, an expert group is currently developing the "Guide to ISO 24194:2022" which offers advice on how to apply the Thermal Power Check and includes important clarifications; this Task 68 document shall be finalized by the time of ISEC 2024 date. This contribution to ISEC 2024 shall focus on SunPeek, the "Guide" document and some applications demonstrating how ISO 24194 can be used and extended for practical purposes. Preliminary results indicate good usability of SunPeek and high potential for ISO 24194 based performance monitoring of solar thermal plants.
Keywords: solar thermal, operation, performance monitoring, open source, ISO standard

INTRODUCTION

Large solar thermal plants (>500m² collector area or 350 kW_{th}) are a key technology to provide renewable heat in residential, commercial, industrial (SHIP), and district heating applications, with substantial growth worldwide in recent years [4]. Heat production costs are stable and competitive (30-60 €/MWh), but only if optimal quality plant operation ensures high energy yields over the lifespan. Two ISO standards provide a framework for quality control of solar thermal installations: The well-known ISO 9806 [2] addresses the performance of single new collectors under lab conditions, generating product data sheets for plant design or simulations; and the ISO 24194 ("Solar energy, Collector fields, Check of performance") [1] introduces two methods for collector arrays: a thermal power and a daily yield method. The Thermal Power Check features a performance number (KPI), defined as the ratio of measured vs. expected plant output, corrected for boundary conditions like weather, temperature levels, heat demand, or system control. This KPI allows for comprehensive plant operation monitoring, but practical implementation of ISO 24194 faces several challenges:

1) Consistency and transparency: While the ISO standard outlines a Performance Check procedure, implementations done by various parties can lead to disparate results, defeating the goal of having a single and transparent source of truth in case of a dispute in an underperforming plant.
2) Availability and usability: Implementing the ISO 24194 methods demands domain knowledge and a deep understanding of the standard, as well as data analysis proficiency and plant-specific configuration. Thus, applying the Performance Check is complex, and resource limitations will effectively impede some parties from using ISO 24194 in practice. Further practical limitations exist, like application to multiple arrays.

SUNPEEK SOFTWARE

To overcome the constraints described in section 2, the authors present SunPeek [5], an open-source software that implements the ISO 24194 Performance Check and is designed to serve as an industry solution and reference implementation of ISO 24194. Additionally, SunPeek provides a framework for other data-driven performance evaluations, quality analysis, and modelling of collector arrays. SunPeek is distributed under open-source licenses that explicitly endorse commercial usage[3]. By adopting an open-source approach, we ensure that the ISO 24194 method is transparent, consistent, and readily available to a broad audience.

SunPeek is designed as a modern web application, featuring a graphical user interface (JavaScript) to speed up the configuration of new plants, a web API, and a backend (Python). Each component is readily accessible online [5], fostering a seamless integration of SunPeek into users' workflows. SunPeek includes a preconfigured demo plant, featuring a full year of open-access measurement data of a subfield of the solar plant "Fernheizwerk" in Graz, Austria [3]. A public demo based on this dataset is available at http://demo.sunpeek.org.

As of now, SunPeek can be applied to typical plant designs and measurement equipment of large solar thermal plants. It does not interfere with system control, facilitating a comprehensive assessment of both present and past system performance. This enables condition monitoring of collector arrays in real operation.

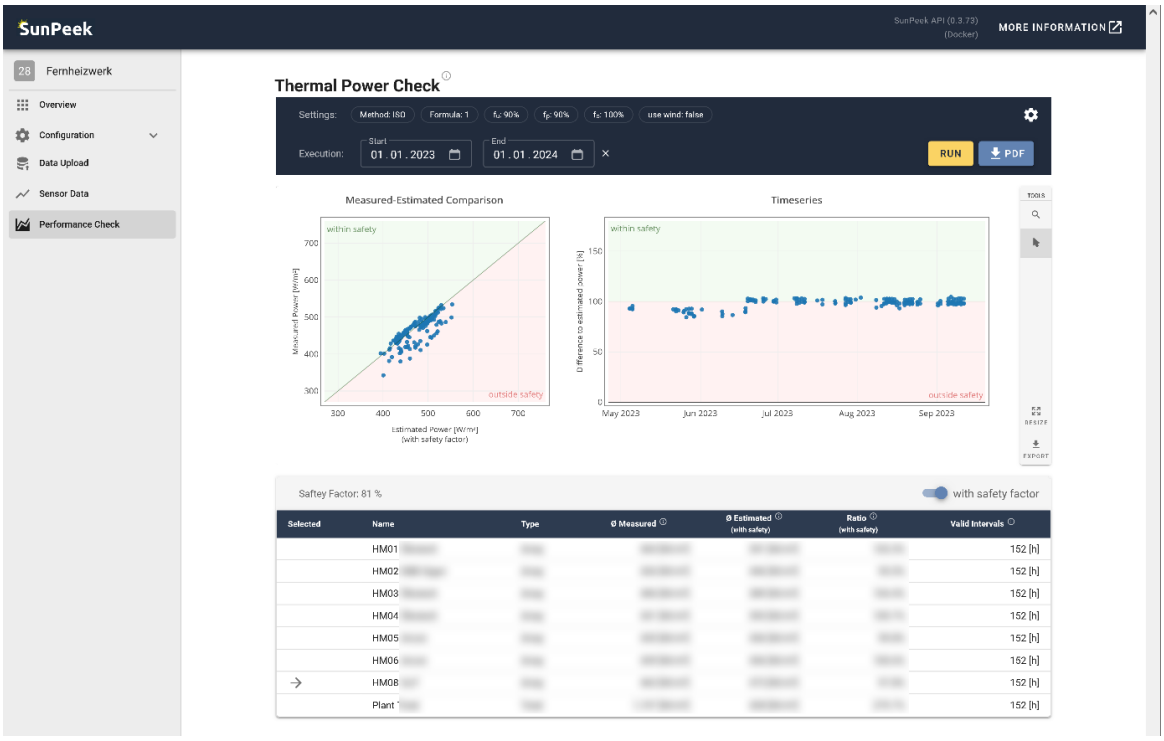

Fig. 1: SunPeek screenshot: ISO 24194 Thermal Power Check results for "Fernheizwerk" plant in Graz, Austria. The left plot illustrates a comparison between measured and estimated hourly performance values; the right plot depicts the evolution of performance values over time. The noticeable pattern shift in the right plot (around mid-June 2023) shows a significant performance increase resulting from cleaning the collector covers.

APPLICATIONS

The authors engage with early adopters from industry and academia, including plant designers, operators, and researchers, who have applied SunPeek for ISO 24194 analysis on their solar plants. Importantly, using SunPeek is possible without sharing measurement data with third parties. Example applications of SunPeek include several Austrian solar plants within the HarvestIT project [9], the EU-funded IndHeap project (with a planned application to concentrating collectors), and the Austrian "Begleitforschung Solare Großanlagen" [8]. Results from these

[3] The Python backend is distributed under an LGPL v3.0 license, see https://opensource.org/license/lgpl-3-0/. The graphical user interface is distributed under a BSD-3 Clause, see https://opensource.org/license/bsd-3-clause/.

applications will be presented in the ISEC presentation, including insights concerning performance development over time, or the effect of cleaning the collector covers. SunPeek has been applied to evaluate large, evacuated tube collector arrays within the HP-BIG project at ISFH [7], funded by the German Federal Ministry for Economic Affairs and Climate Action, and an academic thesis studied the effect of stagnation events on the SunPeek results. Further use cases with SunPeek are foreseen at ISFH within monitoring projects, especially for heat pipe collectors. SunPeek has also been applied to SolarCADII, a solar district heating project in Geneva, using evacuated flat plate collectors manufactured by TVP Solar SA. SolarCADII was monitored by the HEIG-VD Institute in the framework of a research project funded by the Swiss Federal Office of Energy, validating SunPeek with in-house scripts based on 1-minute sampled data; results show strong alignment. SunPeek has been found to streamline analysis and ensure reproducibility of results.

OUTLOOK

Anyone interested in using or contributing to SunPeek is invited to download and try the software [5] or to get in touch with the developers. A future goal is for SunPeek to become a versatile platform, integrating more sophisticated methodologies like energy yield checks, or algorithms required to apply the ISO 24194 in practice, like auto-converting irradiance between differently aligned arrays. One procedure for a solar energy yield check, currently under development, is based on the "Dynamic Collector Array Test" [6] and shall automate the verification of energy yields based on dynamic simulation of the expected solar power. Another procedure for a solar energy yield check is already given within ISO 24194. More research is required to implement these methods, compare their advantages and disadvantages, and assess their applicability for automatic verification of energy yields.

This work has been supported by the Austrian Research Promotion Agency (project HarvestIT, project number FFG 887648, and IEA SHC Task 68, FO999890460) and the European Commission (project IndHeap, proposal number 101136140).

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CONFERENCE TOPICS

- Digitalization for Future Energy Systems
- Renewable Heating and Cooling including high temperature applications
- IT Technologies and Artificial Intelligence
- Smart Services and System Operation

INTEGRATION OF SOLAR THERMAL PROCESS HEAT

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SUMMARY

The standardization of a balance of plant (short: BoP) will be pursued in a solar thermal test plant of the Modulus project in Belgium in a next step. In addition to the developed in-situ test plans for commissioning, the experience gained from the commissioning of the test plant will also be implemented. Commissioning can be divided into a cold and a hot phase, with degassing of the silicone oil also taking place in the former. During the subsequent hot commissioning, heat was successfully supplied to the user.

INTRODUCTION

So far, the defossilization of industrial process heat has only made slow progress. Research and industry are equally in demand here to establish possible alternatives on the market. One possibility is concentrating collector systems such as parabolic troughs, which can be used to generate solar process heat. These systems are able to provide collector temperatures well above 100 up to 420°C and can therefore cover a wide temperature range of the heat required in industry. As part of the Modulus project, the integration of solar process heat at temperatures of up to 380°C is being demonstrated at a site in Belgium. The aim of the project is to drive forward the development of a standardized and modularized balance of plant (BOP) for solar process heat in order to lower the barrier to the integration of solar process heat in industry and ultimately to further promote the defossilization of this sector.

Figure 1 provides an overview of the solar field with BoP and storage. The solar field with a total output of 2.5 MW consists of 3 loops, of which loops 2 and 3 are arranged parallel to each other. Loop 2 and 3 consist of 8 rows with 6 modules each, whereas loop 1 has a larger aperture area, which is compensated for with the help of larger mass flows. All three loops are equipped with a valve for mass flow control at the inlet. The collectors can also be operated with sheep grazing (Figure 2). Further information on the system can be found in previous publications [1] [2].

FIGURE 1: OVERVIEW SOLAR FIELD (PHOTO: AVERY DENNISON)

FIGURE 2: COLLECTOR WITH SHEEP (PHOTO: DLR)

IN-SITU TEST PLAN FOR THE COMMISSIONING OF A BALANCE OF PLANT

After planning a power transfer station, it is also necessary to draw up a standardized test plan for qualification at the production and installation site. The test requirements can be categorized into two different characteristics:

- Origin of the requirement: Product requirements resulting from legal regulations, ordinances or technical guidelines, customer requirements or market requirements.
- Timing of the test: The timing of a test can be relevant for both technical and logistical reasons. Problems that arise during the tests are usually easier and quicker to rectify, and therefore more cost-effective, if the test object is still at the production site

A more detailed description of the defined test criteria will be provided in the paper.

COMMISSIONING OF THE BALANCE OF PLANT

The first step was to set up the control technology software for visualizing and logging the data and for controlling the solar field and the BoP. The hardware required for this had already been installed in the control cabinet at the production site. After an initial plausibility check of the measured values, the filling of the solar field and the BoP could begin. Venting was already carried out at various high points of the system during filling. In the next step, the expansion tank was pressurized with nitrogen so that the heat transfer medium could reach all areas of the system. Once the system had been successfully filled, the measurement signals, in particular the flow measurements, were further checked during pump operation. The first test runs were then carried out. The system was initially operated cold in order to check its stability. This was to ensure that the collectors could be focused when the flow was present. This was followed by further venting of the system, which can be divided into three different processes. First, the circuit was vented as the temperature rose. The system temperature was then stabilized at up to 250°C to boil out the remaining moisture in the pipes and the low-boiling siloxanes from the oil. These were then all blown out via an additional container. Finally, hot commissioning could begin. When starting up, care must be taken to ensure uniform heating on both sides of the heat exchanger. This has the additional advantage that the long pipe to the user is heated at the same time.

Figure 3: Gas blow-off (Photo: DLR)

Figure 4: First heat delivery

The first heat delivery to the customer is shown in Figure 4. This took place without operating the thermal storage. A target temperature of approx. 275°C was specified, which was maintained within the tolerance range required by the customer for several hours.

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications

RENEWABLE HEAT FOR FOOD AND BEVERAGE DRYING PROCESSES – FOCUS ON THE LACTOSOL PROJECT IN VERDUN

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SUMMARY

The abstract proposed by Newheat aims at presenting the renewable heat plant developed and operated by Newheat since March 2023 for the Lactoserum France facility nearby Verdun (eastern France). The abstract will give an overview of the different technologies implemented by Newheat for this project and describe the integration process which allows to supply hot air for a spray-drying tower. A short focus on the role and use of the storage tank will be presented. Finally, the Newheat abstract will expose the benefits of such solutions for food & beverage industrial drying processes.

INTRODUCTION

Lactoserum France is one of the largest production sites for powdered dairy products in France. 80,000 tonnes of whey and lactose are produced yearly on this facility of the Lactalis group in Eastern France. Since March 2023, the Newheat plant Lactosol preheats the fresh air flow used for spray-drying the whey and thus erases a significant part of gas consumption onsite (20% of the drying process heat requirements covered). A heat purchase contract was signed between Newheat and Lactoserum France for a duration of 25 years.

The project was subsidised by the French ADEME (energy agency) as well as by the Region “Grand Est” and the GIP « Objectif Meuse » (local fund).

CONTENT OF THE PROPOSED PRESENTATION

<u>Involved technologies and key figures</u>
This first part of the presentation will give an overview of the plant involved technologies and key figures:

- 12,3 MW solar thermal plant / 14 844 m² solar collectors area / 5 hectares total grand area
- 3000 m3 storage tank
- Energy delivered per year: 8 000 MWh / a
- Tons of CO2 avoided: 2 000 tCO2/ a

<u>Principle of solar thermal integration and key innovations</u>

The whey (co-product of cheese production) arrives in liquid form in the drying tower. The atomizer allows the whey to be projected in the form of very fine droplets into a flow of hot, dry air located in the upper part of the drying tower. The air flow is preheated through the heat exchangers of the renewable heat plant up to 80°C, and a steam battery located in the facility provides top-up to reach a temperature of 160°C. The whey is thus recovered in the lower part of the tower in powder form.

3 integrations within a drying tower:

- Preheating the main air supplying the drying tower

- Preheating the regeneration air of the dehumidification system
- Preheating the air supplying additional applications

Focus on the storage tank

The 3,000 m3 tank built onsite has the following dimensions:

- Height of 12 meters (equivalent to a 4-storey building)
- Diameter of 20 meters

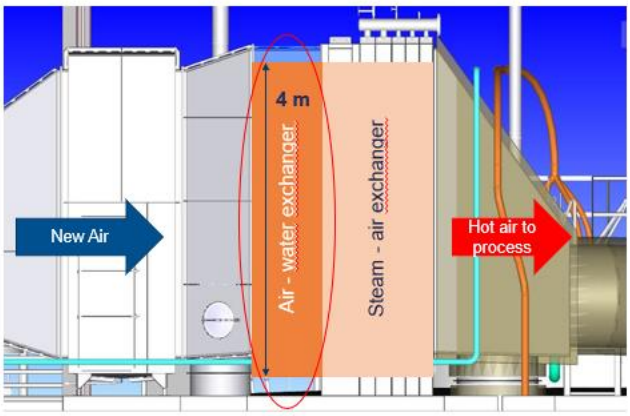
A tank of this size can store about 150 MWh of thermal energy (assuming a "useful" storage temperature range of 40°C), which corresponds to several days of summer production from the heat plant. This is why we call this type of storage "daily". It can in fact make it possible to compensate for the drop in solar resources over a few consecutive days but will be insufficient to cover the deficit in sunshine during the winter period.
Thermal stratification is ensured in the tank, meaning that the temperatures of the fluid are ordered within the tank according to their density. The warmest temperatures are found at the top of the vessel and the coldest at the bottom of the vessel. [4]
Newheat's renewable plant is designed so that the supply (from the solar power plant) and use (by the consumer) of hot water is from the top of the tank, and the withdrawal (to the solar power plant) and return (after supply to the consumer) of cold water is from the bottom of the tank.

Benefits for the site and more generally for F&B sites with industrial drying processes

- CO2 avoidance (2 000 tons of CO2/y) and reduction to fossil fuels dependency of the site (8 000 MWh of renewable heat supplied / year);
- Compliance with food production standards for the work (tool disinfection);
- Ensured production process continuity: neither the connection of the plant nor the renewable plant's operation start required any interruption of the production process of Lactoserum France;
- Preservation of the natural environment: preservation of a pond for an endangered frog species;
- Sheep will graze in the solar field to control vegetation growth.

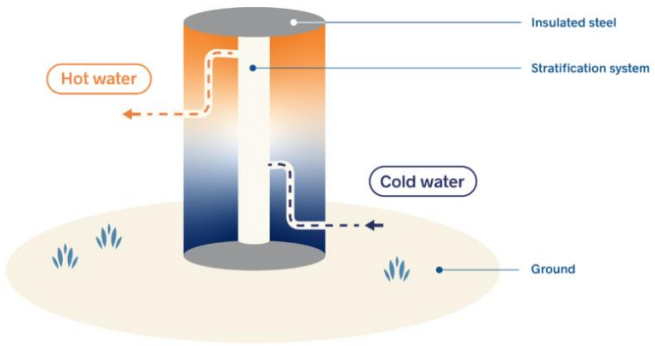
GRAPHICS & SCHEMAS

Installation of the air/water exchanger (10t) in the Lactalis spray drying tower
(source: Newheat)

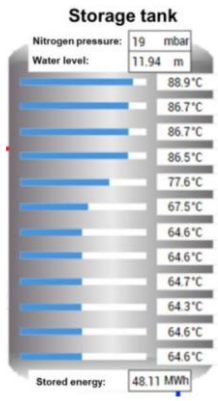


Drying air heating circuit, flow rate 80,000m3/h
(source: Newheat)

[4] See the Newheat blog article on thermal storage.



Water tank for heat storage, source: Newheat



Stratification in storage tanks source: Newheat

Areal view of the Lactosol plant (source: Newheat webcam)

+ a final integration schema of the plant with the 3 heat exchangers will be presented (currently being finalized).

FIGURES

An up-to-date heat load of the facility with supplied solar heat over the year will be shown during the abstract (recent figures being currently updated).

REFERENCES

All information provided come from Newheat's operations feedback or experience. The texts used are Newheat contents.

CONFERENCE TOPIC

Conference Topic to which this abstract refers:

- Renewable heating and cooling, including high temperature applications
- Emerging heat and cold storage

INCREASING FLEXIBILITY IN DISTRICT HEATING SYSTEMS – ELEMENTS AND SOLUTIONS FROM THE THERMAFLEX PROJECT

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SUMMARY

Flexibility in operation and heat sources is an important element of sustainable district heating. Within the demonstration project ThermaFLEX, flexibility concepts were developed. The research and testing focused on the interaction of various components within real district heating networks. We considered and implemented a combination of technical, non-technical, and systemic measures across eight Austrian district heating networks on a large scale. Our efforts led to the development of a diverse range of individual technologies and system solutions aimed at enhancing flexibility and decarbonizing district heating systems. Key elements included heat storage, integration across energy sectors and infrastructures, innovative smart control concepts, widespread adoption of heat pumps, utilization of solar thermal energy, and tapping into locally available heat and waste heat sources. These implemented elements and solutions demonstrate effective utilization and expansion of existing district heat infrastructure.

INTRODUCTION

Currently, district heating (DH) relies heavily on centralized generation, frequently by a limited number of heat-generating plants. Approximately half of this relies on fossil fuels like oil, gas, or coal, with biomass contributing significantly to renewable energy sources. However, for Austria's heat supply infrastructure to transition towards greater reliance on renewable heat, there must be a concerted effort to integrate locally available renewable energy carriers and heat sources. This shift necessitates a move towards increased decentralization within the entire DH sector. As a result, there will be a greater number of generation plants, coupled with the challenge of limited temporal availability and fluctuations in renewable energy sources. This complexity underscores the need for careful planning and management in transitioning towards a more sustainable DH system.

THE FLAGSHIP PROJECT THERMAFLEX

DH systems allow for the integration of renewable energy sources and are highly suitable for measures to increase flexibility and sustainability in terms of renewable supply sources, sector coupling with other infrastructures and local value creation. While DH already plays a large role in the current heat supply in Austria with more than 3,000 operational systems and a share of about 20% of the total heat supply, the share of renewables is only 50% here. Thus, further action is needed to increase this share and to utilize the described benefits, especially with the necessary extension of district heating systems and the phase-out of fossil fuels. To enable the steps for these benefits to be used, system-wide and holistic approaches, as well as scientific methods such as simulation and optimization during conceptualization, implementation and operation, next to innovative technical solutions need to be applied. ThermaFLEX explicitly had the ambitions to tackle the challenges for the implementation of flexible and sustainable DH systems and integration thereof in larger energy supply concepts together with in total 28 partners from research and industry in different demonstration cases and model solutions respectively. A methodology with three different pillars was applied including a) technical measures, b) systemic approaches and c) non-technical measures. Through this intelligent combination and holistic approach, it was possible to a) adapt and further develop existing district heating networks to meet future requirements (e.g., decentralized generation

and storage, load changes, different temperature levels, low summer load with increased heat losses, necessary enlargement, etc.), b) achieve corresponding climate goals, c) establish far-reaching user and stakeholder integration and d) strengthen economic benefits along the value chain.

IMPLEMENTED ELEMENTS AND SOLUTIONS IN REAL-LIFE DISTRICT HEATING SYSTEMS

ThermaFLEX used the linked model solutions to showcase, validate and optimize the developed concepts and used the results and experiences from the implementation and operation to derive Best Practices, highlight promising concepts and pathways and show quantitatively the technical, economic and ecological benefits and impacts of the model solutions and a potential further roll-out. A wide range of different heat sources and flexibility elements were used. The model solutions differ largely in scale, type of challenges addressed and solutions demonstrated. Overall, these experiences are widely applicable for DH systems and can be used as blueprints all over Austria and Europe. In the following, we give a brief overview of these model solutions and highlight their innovative elements:

- High-temperature heat pump: Waste heat utilization from the flue gas condensation of the waste incineration plant as a heat source for a high-temperature heat pump.
- Low-carbon district heating: Use of fluctuating industrial waste heat through bidirectional coupling of two heating networks and development of a high-level predictive control of network and heat generation units.
- Virtual heating plant: Coupling of district heating with the sewage treatment plant in Gleisdorf for heat supply from wastewater and implementation of a novel "virtual heating plant" control system.
- Innovative waste heat utilization at three different demonstration sites: a) Waste heat utilization Therme Wien: utilization of the waste heat available in the thermal water using a heat pump concept and integration into the Vienna district heating system, b) Renewable heat and cooling from wastewater - Wien Kanal: Energy recovery from wastewater for heating and cooling with innovative heat exchanger and heat pump system and c) industrial waste heat utilization: Implementation of an absorption heat pump to increase waste heat utilization at the AustroCel site in Hallein to be fed into the district heating network of Salzburg.
- Modernizing of DH networks: Development of a two-stage modernization concept in Saalfelden. Technical modernization (stage 1) was implemented. A heat pump integration (stage 2) was developed for future integration.
- Large-scale solar thermal integration: Integration of a solar thermal plant of around 5,000 square metres in combination with a 180 cubic metre storage tank into the DH network in Mürzzuschlag.

CONTRIBUTION TO AUSTRIA'S BUSINESS LOCATION

ThermaFLEX utilized a wide range of heat sources and flexibility elements (e.g., heat storage, smart control concepts, large-scale heat pumps). In parallel, highly integrated planning, implementation and operational management processes were applied (e.g. spatial energy planning, life cycle analyses). The measures led to a significant increase in the share of renewable energy as well as to decarbonization and diversification of the respective district heating system. Implementations were realized within the linked model solutions and showcased the great potential of the developed elements and solutions for the decarbonized heat infrastructure in different Austrian cities and regions. Based on monitoring and simulation data climate-neutral heat will be generated in the range between 180 and 200 GWh in future with the realized implementations leading to a substitution of around 45,000 tons of CO_2. Overall, the ThermaFLEX project demonstrated concrete solutions for efficiently using and expanding existing district heating infrastructures. The successful demonstration projects in Styria, Salzburg, and Vienna proved the feasibility of large-scale implementations within relatively short timeframes.

ThermaFLEX is part of the Green Energy Lab, a research initiative for sustainable energy solutions and part of the Austrian innovation programme "Vorzeigeregion Energie" of the Austrian Climate and Energy Fund

THE FUTURE OF LOCAL HEATING AND COOLING PLANNING IN THE EU

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SUMMARY

The decarbonisation of heating and cooling (H&C) systems is essential for reaching climate protection targets and needs planning at local level. In some regions across EU local H&C planning is already state of the art or made compulsory. However, in many regions it is only done sporadically and without clear requirements. This should be changed with implementing the EED recast 2023. In this work we analyse the requirements set out in the EED recast Article 25 and in how far existing H&C plans and regulations are compliant. We find that none of the existing H&C plans nor regulation would fully comply with the requirements in the EED recast. However, the level of compliance is very different and for some plans and policies minor adaptations would be needed. It can be expected that the implementation of the EED recast will push local H&C decarbonization.
Keywords: Energy Efficiency Directive (EED), local heating and cooling plans and national regulations

INTRODUCTION

The transformation of existing H&C systems is essential to reach carbon neutrality. To find efficient and low-carbon H&C systems for a district, city, municipality or region and to transform the existing into alternative systems needs strategic planning: options to increase efficiency, decrease demand and for carbon neutral supply need to be balanced to find suitable alternative systems for an area, and the diverse stakeholders and affected parties need to be involved in this process. In Denmark such local H&C planning processes are regularly performed in all municipalities since the 1980's. In many other countries the importance for local H&C planning is recognised, but legal obligations are still scarce. In the past, cities and municipalities therefore performed H&C planning out of own ambitions, but without a legally binding structure. This changed in recent years in several countries in the EU. In the Netherlands in 2019 the National Climate Agreement was passed. In this agreement municipalities were obliged to develop a vision on the heat transition in their regions until end of 2021 (NL 2019). Also in Germany the political framework became more detailed and binding in the last years. In selected federal states communal heat planning has become obligatory, like in Baden-Württemberg and Hessen (Land Hessen 2022). In 2023 a new law at national level has been presented in draft version and is currently under discussion. When adopted it will oblige all municipalities in Germany to perform communal heat planning according to defined rules.

A boost for setting requirements on local H&C planning in EU Member States (MS) is expected to come with the most recent recast of the Energy Efficiency Directive (EED), which was adopted by the European Parliament in July 2023 (EU, 2023). Article 25 sets out new requirements for local H&C planning: MS need to ensure that regional and local authorities prepare local H&C plans, at least for municipalities above 45 000 inhabitants. For these plans the EED defines numerous aspects that need to be considered and included. Some of the 12 defined points seem to be obvious for the development of a local H&C plan, like to take into account the existing infrastructure, involve all relevant stakeholders or to develop a strategy for the use of the identified potentials. Other points, in contrast, are not that obvious, probably lack in existing local H&C plans and include remarkable efforts to be comprehensively implemented. Examples are to assess the role of energy communities and consumer-led initiatives, the assessment of financial mechanisms or to assess potential synergies with neighbouring municipalities.

Against this background the present work intends to find answers to the following questions: How could the requirements set out in the EED recast 2023 Article 25 be integrated into local H&C plans? In which of the required elements are existing H&C plans (not) compliant with the new requirements? And, do the existing policy frameworks in MS already cover these or some of the requirements set out in the 2023 EED recast?

METHOD

We first analyse how the requirements regarding local H&C planning in the EED recast 2023 could be implemented and integrated into local H&C plans. Hereby, we distinguish between absolute minimum and advanced criteria and prepare them in the form of a checklist. In a second step we look at existing local H&C plans and analyse in how far they comply with the defined requirements following the developed checklist. As a third step we investigate the currently existing policy frameworks related to H&C planning in selected EU MS to understand in how far these already consider or include the requirements defined in the EED 2023, and how strongly they would need to be adapted. We focus our analysis on Austria, Germany and Flanders (Belgium), but also include selected information for other EU MS.

RESULTS

Article 25 of the 2023 recast of the EED will require 1280 municipalities around Europe to develop local H&C plans. While in some MS this affects only a few municipalities (below 10) like SL, CY, ET, LT, LI or CR, in other MS more than 100 municipalities are affected like in DE, ES, IT, FR and PL. Numerous municipalities around EU already have developed local H&C plans in past years. To find an exact number, however, is difficult, as in many MS these are not centrally reported. For the current work we have analyzed nearly 50 existing H&C plans for various municipalities around Europe. We found that none of the analyzed plans fulfils all requirements set out in the recent EED recast. While many of the plans comply with most of the requirements, two of the required aspects are nearly always missing: an assessment of the role of energy communities and other consumer-led initiatives, and the assessment of potential synergies with the plans of neighboring regional or local authorities. An assessment of the potential for low-temperature district heating as well as cooling is also usually missing. The degree to which the different requirements are considered in the plans varies remarkably between different plans. A similar picture emerges from the analysis of the existing policy frameworks related to H&C planning.

CONCLUSIONS AND DISCUSSION

The importance of local H&C planning for the decarbonisation gained more and more recognition and the political frameworks became concreter and partly legally binding in several regions in the EU in past years. The recent recast of the EED with its Article 25 is a next step in this direction with remarkable potential to boost the decarbonisation of H&C. The implementation of political frameworks for obligatory local H&C planning are essential to drive the transformation process. The remarkable number of related requirements formulated in the directive will help to define the frameworks at national levels and to consider all relevant aspects in the process. Especially in those MS where local H&C planning still is not on the political agenda it will help to drive the decarbonisation of H&C.

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CONFERENCE TOPIC

This abstract refers to the Conference Topics “Policies” and “Spatial Energy Planning”.

ESTABLISHING SPATIAL ENERGY PLANNING FOR AUSTRIA'S ENERGY TRANSITION

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SUMMARY

This paper underscores the significance of spatial energy planning as a pivotal instrument for achieving a successful energy transition, using insights gained from the Austrian national project GEL S/E/P. The project aims to enhance spatial energy planning processes by introducing a standardized energy atlas that provides geodata and automated reports. By emphasizing the key components and output data layers of the atlas, this paper showcases its practical applications in the context of local development planning. Moreover, the introduction of a user-friendly GIS-based web service, powered by the energy atlas database and the open-source LizMap client, is highlighted for its role in engaging various professionals, including energy planners, city planners, civil engineers, and energy specialists in public administration.
Keywords: Spatial Energy Planning, GEL S/E/P Project, Energy Atlas, Geodata, Automated Reports, GIS-based Web Service, Local Development Planning, Municipal Heat Planning, Energy Transition

INTRODUCTION

GEL S/E/P - Spatial Energy Planning for Energy Transition

Since its inception in 2019, the GEL S/E/P project series [1] has been dedicated to laying the groundwork for effective spatial energy planning. Focused on Salzburg, Styria, and Vienna provinces, the project aims to develop a tailored digital energy atlas with high-resolution spatial information and reporting functions. Engaging with authorities and policymakers, it addresses legal framework conditions. The energy atlas includes detailed data on buildings, renewable energy potentials, and grid-based infrastructure, facilitating municipal energy system analysis and planning [2, 3, 4]. In its initial phase, the project established the Spatial Energy Planning (SEP) system for the heating sector. The subsequent phase expands it to mobility and electricity, creating a cross-sectoral information platform. The project enhances results, supports federal states in SEP execution, and contributes to defining regulatory conditions. Overall, the GEL S/E/P initiative represents a significant step towards a more streamlined and efficient approach to spatial energy planning in Austria, contributing to the broader goal of a successful energy transition.

To enhance accessibility, the energy atlas will be available to communities through on-demand web services, primarily using Web Map Services (WMS) from federal state GIS systems like ViennaGIS, GIS Steiermark, and SAGIS Salzburg. The prototype's deployment is actively progressing in demonstration regions, with a full operational launch expected by May 2024.

Practical applications for spatial energy planning and GIS-based services

The practical applications of data extracted from the energy atlas span various aspects of local development planning. One significant application involves the formulation and execution of local and regional climate action plans. Utilizing the detailed spatial information on renewable energy potentials and energy infrastructure provided by the energy atlas, municipalities can craft targeted strategies to reduce carbon emissions and bolster sustainability. The atlas facilitates the identification of suitable areas for renewable energy installations, thus integrating clean energy sources into climate action initiatives.

Building renovation and decarbonization roadmaps represent another critical application area where the energy atlas plays a pivotal role. By employing the advanced building energy model and detailed spatial information on buildings, municipalities can develop comprehensive plans to renovate and decarbonize existing structures. Likewise, municipalities can optimize the planning and implementation of district heating systems by analyzing data on local renewable energy potentials and energy demand. This involves identifying suitable locations for district heating hubs, assessing the feasibility of integrating renewable energy sources, and ensuring efficient heat distribution across strategic zones.

Zoning and infrastructure planning also have a strong connection to the electricity sector. In the context of photovoltaic (PV) installations, the energy atlas provides insights into optimal locations for solar energy generation. It aids in determining areas suitable for electricity grid expansion to accommodate increased renewable energy capacity. Moreover, it supports infrastructure planning for the deployment of heat pumps and electric vehicle charging stations, contributing to the overall advancement of sustainable urban development.

To enhance the accessibility and utility of the data foundation for specific application domains and stakeholders in spatial energy planning, the authors have recently focused on developing more versatile GIS-based services. This paper sheds light on databases, selected methodologies, and resultant output layers of the GEL S/E/P energy atlas, emphasizing practical use cases encountered in spatial energy planning. Notably, the chapter introduces a user-friendly spatial energy planning tool that leverages the open-source LizMap web client. The tool is designed with a low-threshold entry point, ensuring accessibility for diverse stakeholders and applicability to various use cases in spatial energy planning.

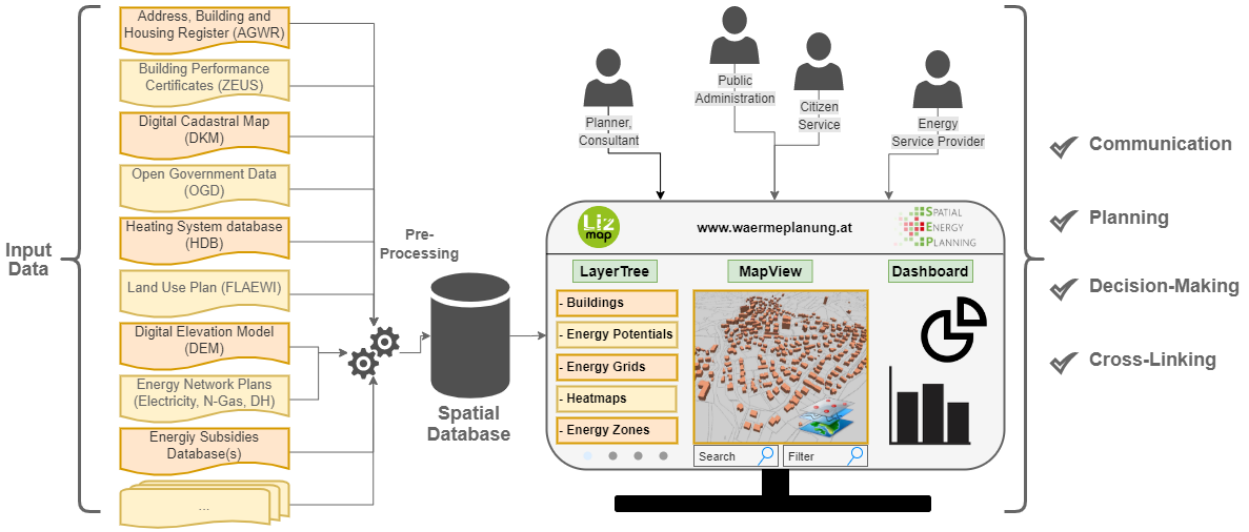

Fig. 1: GIS-based service environment for spatial energy planning in cities and communities

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CONFERENCE TOPIC

Spatial Energy Planning (cross-cutting theme)

SPATIAL AGENT-BASED MODELLING AND SIMULATION TO EVALUATE ON PUBLIC POLICIES FOR ENERGY TRANSITION

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EXTENDED ABSTRACT

Our energy system is undergoing rapid change. New technologies and opportunities such as electromobility, digitization, energy communities or low-temperature heating networks are entering the market, which must be reconciled with societal demands for greater sustainability and political commitments such as the Austrian heating strategy with the goal of decarbonizing the heat supply for buildings by 2040. This poses a high level of complexity for decision-makers in politics, energy supply and business.

An energy-efficient and climate-friendly heat supply of the future now requires planned action, the modernization of the existing building stock, a sustainable orientation of new buildings, and the conversion of the heating and cooling supply to renewable energy sources. Not only will infrastructure and technology change, but the use of buildings will also be transformed by digitalization, and administrative as well as planning processes must do justice to this system complexity. In addition to the spatial dimension of energy supply and demand, increasing importance must also be attached to the social dimension of the energy transition in planning and decision-making processes. The behaviour and decision-making patterns of central actors (politics, public administration, planners, investors, energy supply companies, population), each with their own specific roles, needs and values, are highly relevant to planning in the context of heat and energy transition, but are, if at all, hardly considered in current processes.

This combination and integration will be addressed in the project ABM4EnergyTransition complementing existing (spatial) planning approaches and spatial Agent-based Modelling (ABM) approaches (see Figure 1). Classical modelling and planning approaches of the heating and energy transition primarily focus on the techno-economic aspects of energy demand and provision. In doing so, they not only neglect the spatial dimension, but also complex interactions between technology, business and politics and their influence on the decision-making behaviour of key players in our energy system. Agent-based modelling and simulation (ABMS) is an ideal tool to make such complex interactions understandable from the bottom up and in a spatial context (Heppenstall et al., 2011). Using ABM, different actors in a system can interact with each other and with their environment as autonomous agents, each with different properties, differentiated decision-making behaviour and the ability to learn. This makes ABM particularly useful when considering and analysing complex, multilevel problems with very heterogeneous influencing factors, as represented by an energy system. ABMs are widely used to simulate social, economic and environmental problems (Heckbert et al., 2010; Gotts et al., 2003). More recently, ABM has also been used increasingly in the field of energy transition research, in particular with a focus on the electricity sector (Hansen et al., 2019) or to investigate the dynamics in the development of the building stock (Preisler et al., 2017; Nägeli et al., 2020)

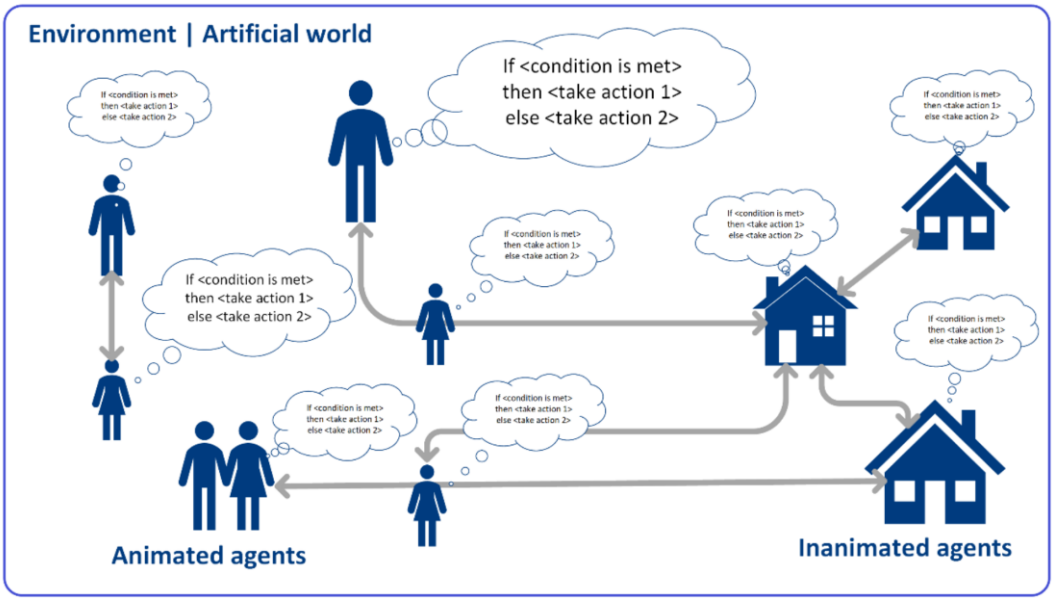

Fig. 1: Schematic structure of an ABM, which consists of an environment and the agents acting in it and their interactions. Adapted from Crooks et al. (2018).

The objective of ABM4EnergyTransition is the development and demonstration of a novel simulation approach based on ABM for the spatial analysis and assessment of pathways for the municipal heat and energy transition. The ABM methodology considers both spatial information to describe the energy system of a study area (buildings, grid-based energy infrastructure such as natural gas or district heating networks, renewable potentials, population structure) and parameters to describe the behaviour of actors (agents), like homeowners, investors, policy makers. In addition, the simulation system considers demographic and socio-technical parameters such as income and state of education. The methodological approach represents an extension of existing energy planning approaches and helps to better assess the impact of public policies on the achievement of climate and energy goals. The methodology of the project is of an interdisciplinary character, and involves Spatial Analysis, Spatial ABM and Simulation, Energy Planning, as well as Software Engineering and a Social-technical empirical approach. Based on a large survey that was sent out to households in the Province of Styria (Austria), we are able to accurately model the behaviour of people with different socio-economic backgrounds in varying geographical contexts accurately using ABM technology.

The tangible results are a prototypical map centred web application with a dashboard and the representation of the ABM results. The spatial temporal data in addition with buildings and energy infrastructure are represented best in a cartographic way. The Dashboard allows users from administration and planning to plan possible energy policy and/or technical interventions in the ABM and to display the results (e.g.: Energy and Life Cycle Assessment as well as technology and energy carrier mix in variable spatial and temporal granularity, etc.). In addition, simplified simulation scenarios can also be initialized and visualized by interested citizens in the web application for a playful examination of the topic of heat transition and energy system change (see Figure 2).

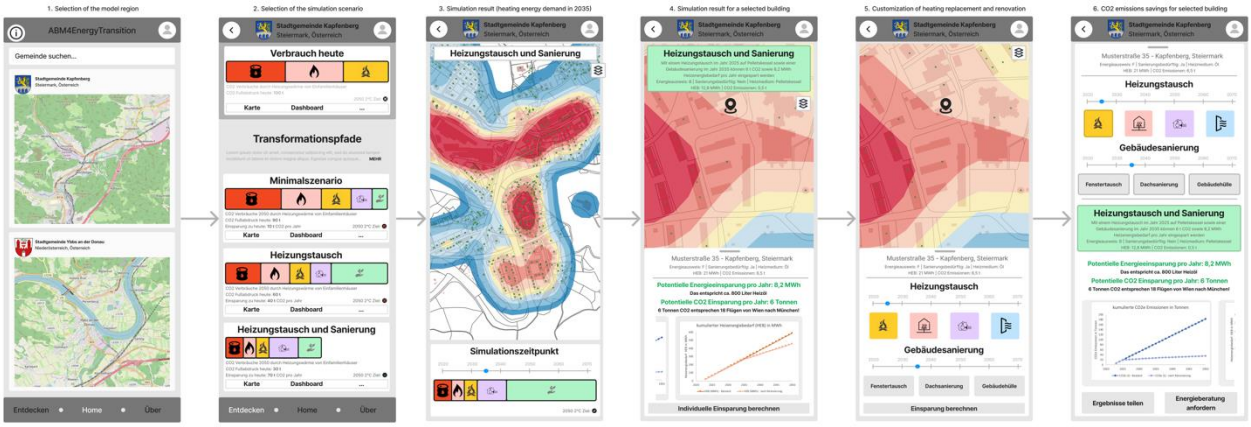

Fig. 2: Wireframes of the Demonstrator application (Work in progress).

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INTEGRATED SUSTAINABILITY ASSESSMENT OF A RESIDENTIAL HEAT PUMP SYSTEM

Approach, Data Requirements, and Integration of a Dynamic Electricity Mix

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SUMMARY

As there is currently a lack of reliable guidance for investors to make the most sustainable choice when it comes to different renewable heating technologies for residential buildings, this contribution presents a methodological approach for a comprehensive comparison, while also addressing data requirements. A focus point of the methodology development and the sustainability assessment lies in the integration of a dynamic electricity mix to account for the continuous decarbonization in an energy grid that is more and more based on renewables. The regarding influence on the final environmental impact results of the presented exemplary system combining a solar-thermal collector and an air-water heat pump will be assessed and a sensitivity analysis of the overall environmental impact results of the system to specific standardization choices will be performed.

INTRODUCTION

Currently, about 17.4 % of the German heat demand are covered through renewable energies (Umweltbundesamt (UBA), 2023). While biomass is still the largest contributor in the renewable heating market, its share is decreasing. There has been a rapid increase in the utilization of geothermal and ambient heat through the deployment of heat pumps (especially air-source heat pumps) in the past five years (Bundesverband Wärmepumpe (BWP) e.V., 2023). Also, other renewable heating technologies are growing in the market. Currently, roughly 5% of the German heat demand is covered by solar thermal collectors. (UBA, 2023)
Renewable energies cover a wide range of technologies. While all technologies cause environmental impacts during their production and end of life phases, the impacts associated to the respective use phases can differ quite significantly. For solar thermal collectors, the use phase is mostly emission-free. The impacts allocated to the use-phase of heat pumps are strongly dependent on the electricity mix and the system-efficiency. Biomass as a third example causes direct emissions through the burning process. However, emissions from biomass use are considered as biogenic and not fossil emissions. Therefore, currently biomass is declared to be a carbon neutral energy source. Similarly, costs and potential revenues can differ quite significantly over the lifetime of these systems. Due to this variety in technologies a comprehensive comparison based on both environmental impacts and economic performance is not yet available and investors are lacking reliable guidance for sustainable decisions.

Environmental impacts are quantified and assessed through the life cycle assessment (LCA) methodology. While the general approach is standardized in the ISO norms DIN EN ISO 14040 and 14044, there is still a lot of room for individual choices. This leads to a lack of comparability in the results. Different system boundaries, functional units and impact assessment methodologies make comparisons of LCA results among different studies in many cases impossible. For some technologies, further recommendations and standardizations are available to allow for a fair comparison. However, this is mostly technology specific and does not allow for comparisons of different technologies. In the German Project “Effizientes Heizen” (efficient heating), the project team aims to close this gap by developing a comprehensive approach and guidelines to assess and compare a variety of different heating

technologies with regards to their economic and ecological performance. Internationally, this is also supported through the IEA SHC Task 71.
This contribution focuses on the developed methodological guidelines regarding the ecological impacts (LCA), while applying them exemplary to a combined solar thermal and air-source heat pump system.

METHODOLOGY

To make LCA results comparable across technologies, key parameters must be defined and standardized. Most importantly, the system boundaries of the LCAs must be harmonized. This includes the decision on which life cycle stages are assessed (raw material extraction, production, use phase, recycling and/or disposal), as well as the definition of the product system: Does the LCA include an entire heating systems setup (e.g., heat generator, heat storage, and distribution) or is the focus solely on a specific component or technology (e.g., heat generator). For a comprehensive, fair, and application-oriented comparison, this project focuses on heating systems over their entire life cycle. To further enhance comparability, the system layout is based on standardized demand side scenarios. Heating systems are designed to meet the demand of predefined reference buildings (single and multi-family houses, newly built and building stock). As a functional unit 1 kWh of provided heat is used. The unification of the functional unit is essential to make LCA results comparable. The third key factor in standardizing LCA setups is the choice of the life cycle impact assessment method. Following recommendations by the European Commission, the EF3.0 Methodology is selected (European Commission, 2023), while relevant impact categories are identified by performing hot spot analyses. The chosen system model is cut-off, while environmental credits, potential loads and benefits beyond the system boundaries may be listed separately, as for example the recyclability of products. Data requirements and quality standards must be clearly defined, as well as the procedure on how to fill potential data gaps. Approaches for harmonized data sets for different heating technologies are presented.
While the harmonization of these (rather methodologically focused) aspects allows for limited comparisons of the LCA results, further guidelines and the definition of technological and other input parameters is required. These include among others the lifetime of the systems and its components, the efficiency, degradation rates and patterns, the location of installation, the end-of-life treatment of components and the applied electricity mix. As mentioned earlier, impacts allocated to the use phase of heat pumps are strongly dependent on the electricity mix. With increasing RE deployment, the electricity is continuously decarbonized. Instead of assuming the current electricity grid mix for the entire use phase of up to 20 years, a dynamic electricity mix model is integrated in the modelling of the system, to account for these developments. This is presented as an example to analyze sensitivities of results to selected input parameters.

RESULTS

The methodology allowing for a fair sustainability-oriented comparison of different heating technologies for domestic buildings will be presented and a proof-of-concept will be given by analyzing the environmental impacts of a combined solar thermal and air-source heat pump system. The sensitivity of the results on the influence of certain standardization choices on the overall environmental impact results of the system is assessed. The focus of the presented results will lie on the influence of the integration of a dynamic electricity mix in the LCA. Expecting a system lifetime of at least 20 years, the carbon footprint of 1 kWh of electricity supplied by the German grid mix is expected to decrease by roughly 80% in the same timeframe. By applying a dynamic grid mix, the climate change impacts associated to the annual electricity consumption of the heat pump in the use phase are on average roughly 50% lower, compared to simply applying the current electricity mix.

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ACKNOWLEDGEMENTS

This work is conducted within the project “Effizientes Heizen” funded by the German federal Ministry for Economic Affairs and Climate (BMWK, funding code: 03EN6014A/B). In the project, experts from leading research institutions and industrial companies are working over a period of three and a half years to develop and apply an integral evaluation methodology for ecologic and economic sustainability assessments of solar-based renewable heating systems in comparison with alternative systems.

CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers: Life Cycle Assessment

URBAN OVERHEATING: INNOVATIVE INTERVENTIONS IN GÜSSING

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SUMMARY

The "Cool-down Güssing" smart cities research project (financed by Klima- und Energiefond), set in Güssing, Austria, pioneered innovative solutions to counteract summer overheating in urban structures. Focusing on diverse building types, the initiative successfully retrofitted structures with eco-friendly cooling systems. 9 demonstration buildings (commercial, residential and public buildings) benefited from tailored strategies, resulting in higher levels of comfort. Crucially, the project demonstrated a significant reduction in energy demand for space cooling, with user feedback underscoring the tangible improvements in living and working conditions. This demonstration project is evidence of the potential of collaborative research in addressing urban climate challenges.

INTRODUCTION

In recent years, urban areas worldwide have grappled with the escalating issue of summer overheating, a phenomenon exacerbated by climate change. Güssing, a city in Austria, became the focal point of a groundbreaking research project titled "Cool-down Güssing." Spearheaded by Güssing Energy Technologies (GET) and supported by a consortium of experts, the project embarked on a 42-month journey to confront the challenges of rising temperatures. Recognizing the adverse effects of increased heatwave days on the quality of life and the subsequent spike in energy consumption, the initiative sought to retrofit existing buildings with innovative cooling systems. This introduction delves into the project's objectives, the collaborative approach adopted, and the diverse building types addressed, setting the stage for a detailed exploration of the project's outcomes and implications.

COOLING TECHNOLOGIES

In the "Cool-down Güssing" project, a range of technologies were explored to address the challenges of summer overheating. One of the primary strategies was the prevention of heat ingress. This was achieved through building greening, which not only minimized heat entry, especially through the roof, but also offered additional benefits like water retention. The importance of shading was emphasized, especially for windows, as unshaded windows can significantly contribute to indoor heat. Examples highlighted instances where shading was either absent or improperly used, underscoring the need for effective sun protection.
Another technology used was night ventilation, which leverages cooler outdoor air during night time to cool buildings. This strategy, while not novel, was applied in the context of the project to understand its efficacy in the selected demo buildings. The decentralized ventilation system offers targeted air exchange, improving indoor air quality while aiding in the reduction of excessive summer heat in buildings. Adiabatic cooling utilizes the principle of evaporative cooling, where water is evaporated to absorb heat, providing a natural and energy-efficient method to cool indoor spaces. The ground heat exchanger harnesses the stable temperatures of the earth, facilitating the pre-cooling or pre-heating of incoming air, optimizing indoor thermal comfort throughout the year.

The project's approach was not to develop new technologies but to implement and assess existing ones in real-world scenarios.

AHP METHOD

The Analytic Hierarchy Process (AHP) method played a pivotal role in decision-making. This systematic approach allowed stakeholders to weigh and prioritize various cooling solutions by integrating multiple criteria. Beyond just economic considerations, the AHP method incorporated technical, social, and environmental factors, ensuring a balanced and comprehensive evaluation. The application of AHP ensured that the selected solutions were not only cost-effective but also sustainable and aligned with the broader objectives of the community and the environment.

EXAMPLES AT DEMO SITES

Specific measures were implemented in different buildings to combat summer overheating. At the garage door production company Guttomat, a unique approach was taken by utilizing the flaps of the smoke extraction system for night ventilation at their production hall. This measure capitalized on the cooler nighttime temperatures, allowing fresh air to circulate throughout the building, thereby reducing the indoor temperature. The results were promising, with a noticeable reduction in daytime indoor temperatures, enhancing the comfort levels for the occupants. Compared to measurements without night ventilation, the room temperature in the hall was 22 °C in

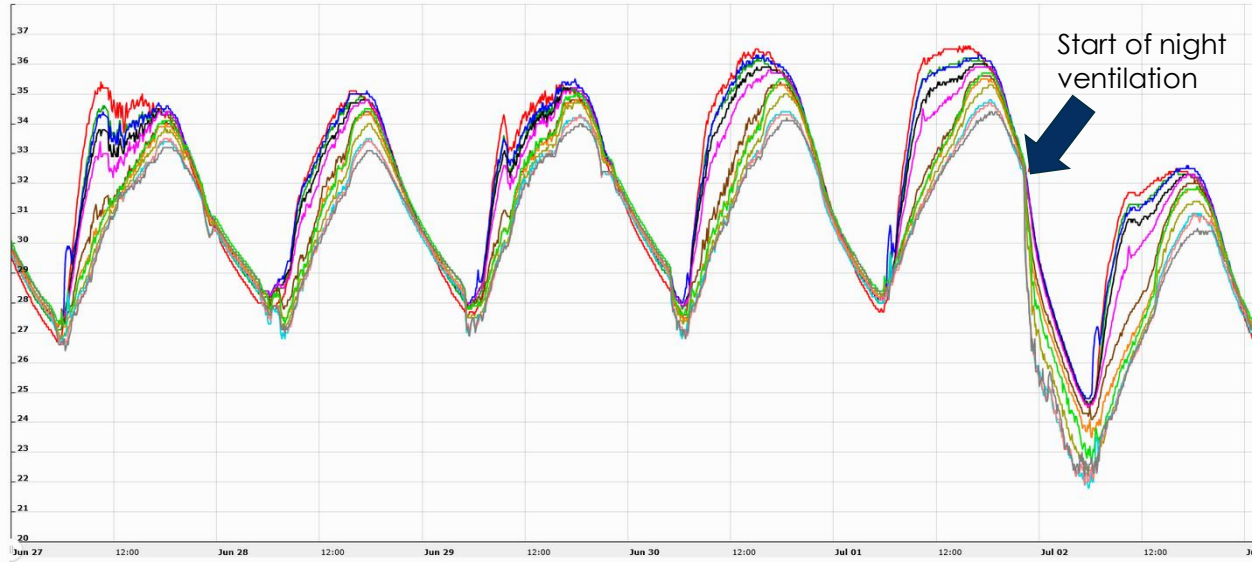

Figure 21: Effects of night ventilation on the room temperature in the production hall between 4 and 5 K the morning, instead of 27 °C (previously), and 27 °C at midday, instead of 31 °C (previously).

At the BORG Güssing (school), decentralized night ventilation was introduced. This method involved the use of individual ventilation units placed strategically in various parts of the building. These units operated during the night, drawing in cooler external air and expelling the warmer indoor air. The advantage of this decentralized system is its ability to target specific areas or rooms, ensuring optimal cooling where it's most needed. Post-implementation, the feedback was overwhelmingly positive. The classrooms experienced a significant drop in temperatures (between 2.5 and 4.5 K), creating a more conducive learning environment for students. Moreover, the energy efficiency of these decentralized units made them a sustainable choice, aligning with the broader goals of the project.

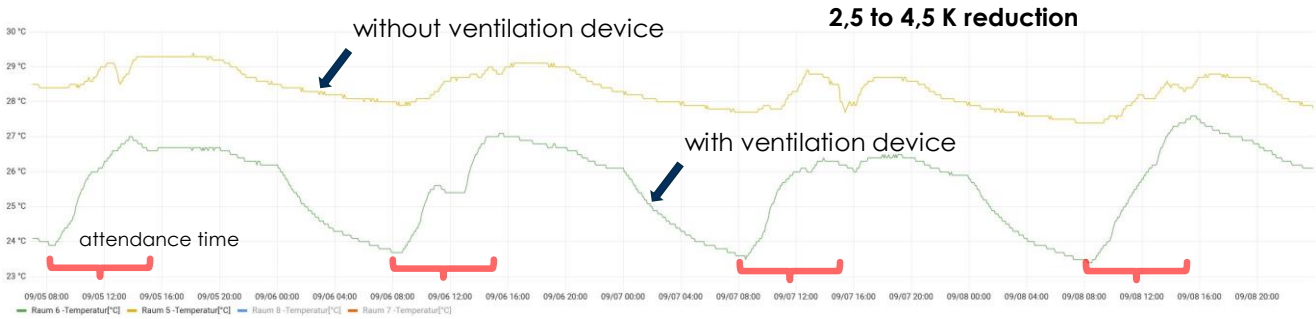

Figure 22: Comparison of the room temperatures of two classes (east) with and without a decentralized ventilation device

In the Kindergarten Güssing a targeted approach to combat summer overheating was employed through the implementation of night ventilation using actuators on the windows. These actuators allowed for automated control, ensuring windows opened during cooler nighttime hours to facilitate the inflow of fresh air. As the cooler air circulated, it effectively reduced the indoor temperatures, ensuring a comfortable environment for the children by the time they arrived in the morning. The results post-implementation were significant. The indoor temperature saw a noticeable drop, enhancing the comfort levels within the rooms. This measure not only ensured a conducive environment for the children but also showcased the project's dedication to integrating smart, energy-efficient solutions in existing structures.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Solutions for Energy Efficiency
- Sustainable Renovation

BUILDINGTWIN - OPEN PLATFORM FOR MONITORING, EVALUATION AND OPTIMIZATION OF BUILDING OPERATION

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SUMMARY

Keeping track of all data about a building over its entire life cycle is a major challenge. Planning data, like the building information modeling (BIM) data, is often not carried over into the operational phase. The "as-built" state is commonly documented in various lists and data sheets, independently of the BIM model. And usually neither real-time nor historical data on the operating status of the building is available. This lack of data makes it hard to operate a building in an optimized and efficient manner.
We demonstrate the web-based platform "buildingTwin" to aggregate all building relevant data in a centralized "digital twin" model of the building, combining BIM data from the planning phase, data sheets and attributes documenting the "as-built" state, and real-time measurements from sensors and other sources during the operational phase. This platform provides easy access to all building data and enables monitoring, evaluation, and optimization of the building operation. *BIM, IFC, digital twin, sensors, visualization, building operation.*

INTRODUCTION

Digital tools are already commonly used during the lifecycle of a building. During the planning phase, a digital model of the building and related planning data, the BIM model, is created. This model is used as the basis to derive plans for the construction process, during which the BIM model may also be enriched with additional data. On the other hand, in the operation phase, CAFM software is used for maintenance management. However, there is typically an information gap between these phases. The planning data from the BIM model is not used by the CAFM software for building operation. Similarly, maintenance information is not fed back into the BIM model. Additionally, real time information about the current state of the building is not easily available, even though many buildings have various sensors and measurement devices installed. But to be able to efficiently operate a building with minimal resources, all this information is crucial.

We propose a web-based platform, buildingTwin, to collect, manage and retrieve all information of a building in an easy and accessible way. The foundation is the BIM model of the building from the planning phase, which is enriched and updated with additional data, like data sheets and real-time measurements. The web-based platform allows anyone to access this data from any device without requiring special BIM software. This enables low friction contribution of data, e.g., by executing companies during the construction phase, to provide data sheets, product details or warranty information. The collected information provides a detailed view on all building related data in an accessible way and enables efficient building operation.

IMPLEMENTATION

The buildingTwin platform is based on the open BIM standard IFC (buildingSMART International, 2017) which is a common exchange format between BIM applications of different vendors. Using an open standard ensures that BIM models from every software vendor can be used with the platform.

From the provided IFC BIM models, the geometric 3D building representation, metadata for all building elements, as well as all attributes assigned to individual elements are extracted. Following the IFC standard, all attributes are grouped into collections called property sets.

The web-based user interface provides easy access to the 3D representation of the building, a searchable list of all building elements, and to all property sets and their attributes. Attributes can be supplemented and updated by the user directly in the web browser, without requiring access to special BIM software. Users can also upload documents like data sheets or photos and link them to individual building elements. To monitor the current state of the building during operation, the platform also visualizes real-time measurements, which can be collected using a wide variety of protocols like HTTP, MQTT, Modbus, BACnet and others. The measurements can be linked to individual building elements and visualized in the 3D model, as shown in Fig. 1.

Fig. 1: Screenshot of the buildingTwin web application visualizing real time sensor measurements on the 3D BIM model of a small office building. Labels in the 3D model indicate the name of each room, taken from BIM attributes of the model.

Having all data easily accessible on the platform allows it to be used as the basis for additional smart services like energy efficient building automation, where real-time data and attributes are used to control equipment and devices in the building. For example, we have successfully implemented an automatic control of the ventilation system of an office building, based on real time measurements from room and outdoor temperature sensors and additional CO_2 sensors monitoring indoor air quality.

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CONFERENCE TOPIC

- IT Technologies and Artificial Intelligence
- Smart Services and System Operation

USERS' IMPACT ON BUILDINGS' ENERGY PERFORMANCE GAP

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SUMMARY

Prior to implementation of new building (or building retrofit) projects, buildings' future energy demand is regularly predicted for certification or optimisation purposes. However, there is often a deviation between the projected and actual energy use during buildings' operation. A number of different factors can contribute to this mismatch that is typically referred to as energy performance gap (EPG). These could be due to uncertainties regarding weather conditions, buildings' systems, construction, and geometry. Specifically, issues regarding occupants' behaviour and related control actions have recently been suggested to be a major cause for the EPG. However, evidence for such a claim is not conclusive. In this context, this contribution explores the impact of occupants' control-oriented behaviour (e.g., interactions with buildings control components and systems, such as opening or closing windows or adjusting thermostats) on buildings' energy performance. Furthermore, a discussion outlines strategies that balance occupants' control opportunities and energy efficiency targets.

Keywords: buildings, energy performance gap, occupant behaviour, simulation

POTENTIAL CONTRIBUTORS TO BUILDINGS' ENERGY PERFORMANCE GAP

Different factors can contribute to the deviation between the projected and the actual energy use during buildings' operation (Menezes et al. 2012, Andersen et al. 2016). Examples of such factors include: i) Energy performance predictions include assumptions regarding future weather circumstances, which can be highly uncertain; ii) Buildings' construction can deviate from initial design in the realisation stage. Likewise, buildings' implemented systems (e.g., heating, cooling, ventilation, lighting) and their operation may not reflect the design-phase intentions; iii) Assumptions regarding the interaction between future building users and environmental control elements are seldom accurate; iv) Mistakes may occur in the usage of computational tools (e.g., input data or settings could be incorrectly assigned). Also, may not have been carefully examined with regard to their fidelity and validity; v) Deficient monitoring infrastructure and inconsistent documentation may lead to errors in the accounting of actual consumed energy magnitudes. It has to be noted that, given the stochastic characteristics of occupants' behaviour and weather conditions, energy performance calculations can only be evaluated according to the assumed model input data. Hence, the impact of occupants' behaviour can only be evaluated separately if other potential influencing factors have been accounted for via normalisation (Berggren and Wall 2017).

EMPIRICAL EVIDENCE OF OCCUPANTS' ROLE IN THE EPG

A recent effort reviewed the evidence for the claim that occupants are the main reason for the energy performance gap (Mahdavi et al. 2021). Thereby, 144 relevant scientific articles were assessed with regard to quality and content. These included studies that focus on the EPG in both residential and non-residential buildings located in different climatic regions. The review results indicate that building's actual energy use has been both under and

overestimated. According to the reviewed studies, the median value of EPG was +30% in case of residential buildings and +14% in case of non-residential buildings. Around 70% of the reviewed studies indicate some instance of EPG linked to buildings' envelope, mechanical equipment, plug-loads, lighting, and internal heat gains. Frequent stated EPG causes among the reviewed studies were plug-load schedules (reported in 40%), window operation (reported in 36%), and set-point temperature (reported in 33%). Multiple studies report some form of an occupant-related EPG. However, evidence for occupants' role in the EPG is not consistently provided. The review results also show that only 14% of the studies include data concerning both energy use and occupant behaviour. A subsequent research effort specifically focused on this qualitative aspect of the reviewed studies (Amin et al. 2022). Thereby, quality labels were assigned to three different criteria, including data quality, extent of normalisation, and the applied method to identify the cause of the EPG. The results of this study suggest that the documented EPG magnitudes were considerably higher in lower quality studies.

MITIGATION OF THE POTENTIALLY NEGATIVE USER BEHAVIOR EFFECTS

As outlined above, previous research has not provided definitive empirical evidence to support the claim regarding the prevalence of occupants' responsibility for EPG. Nonetheless, existing case reports do suggest that, in specific cases, occupants' behaviour may adversely affect buildings' energy performance, thus encouraging strategies that could help obviating respective negative implications. Specifically, two strategies are outlined in the following: First, consideration of certain features of the adopted building design and technology can be critical. These included especially opting for a high level of zonal granularity or smart zoning. Also, occupants' satisfaction with and understanding of environmental control opportunities can be enhanced by including intuitive and responsive user interfaces as well as providing personal control opportunities to offer the possibility to maintain preferred environmental conditions in the users' immediate surroundings. Another strategy concerns the targeted and timely provision of information to building users. Occupants should be supplied with information on how to operate available interfaces, systems, and equipment in an appropriate manner. Moreover, information campaigns and real-time feedback regarding sources and magnitude of energy consumption can improve occupants' awareness towards buildings' energy performance. These strategies can contribute to improving both occupants' satisfaction and building' energy performance.

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CONFERENCE TOPIC

Solutions for Energy Efficiency

A CASE STUDY OF NINE POST-HYDROCARBON READY HOMES

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SUMMARY

Howgate Close is a residential neighbourhood of nine naturally heated, naturally cooled homes, operating free of fossil fuels while generating a net annual surplus of renewable energy. This residential development is located in the county of Nottinghamshire, UK where construction was completed in June 2022. Each home's average daily energy bill, for the first 15months of occupation is 10pence/day/dwelling, inclusive of Standing Charge (Octopus, 2023)

Howgate Close is a cost-effective residential building solution that operates as a net annual generator of surplus renewable energy, with little to no heating demand. The projects exceptionally high levels of energy efficiency achieved an AS-Built SAP Rating of 143A (HM Government, 2022) This result places these homes in the top 0.01% of the 12million registered UK Energy Performance Certificate's (EPC)

INTRODUCTION

Howgate comprises, nine homes, 5no. 2beds (63m^2) and 4no.1beds (41m^2) with a gross development floor area of 479m^2. The projects financial viability has been tested in the open market with construction costs of £2,100 m^2, costs that compare favourably with £1,800 m^2 for a conventional dwelling (Eagle Building, 2020) and £2,200-2,400 m^2 for a Passive House. As a result, Howgate's development Return On Investment is 4.6%.

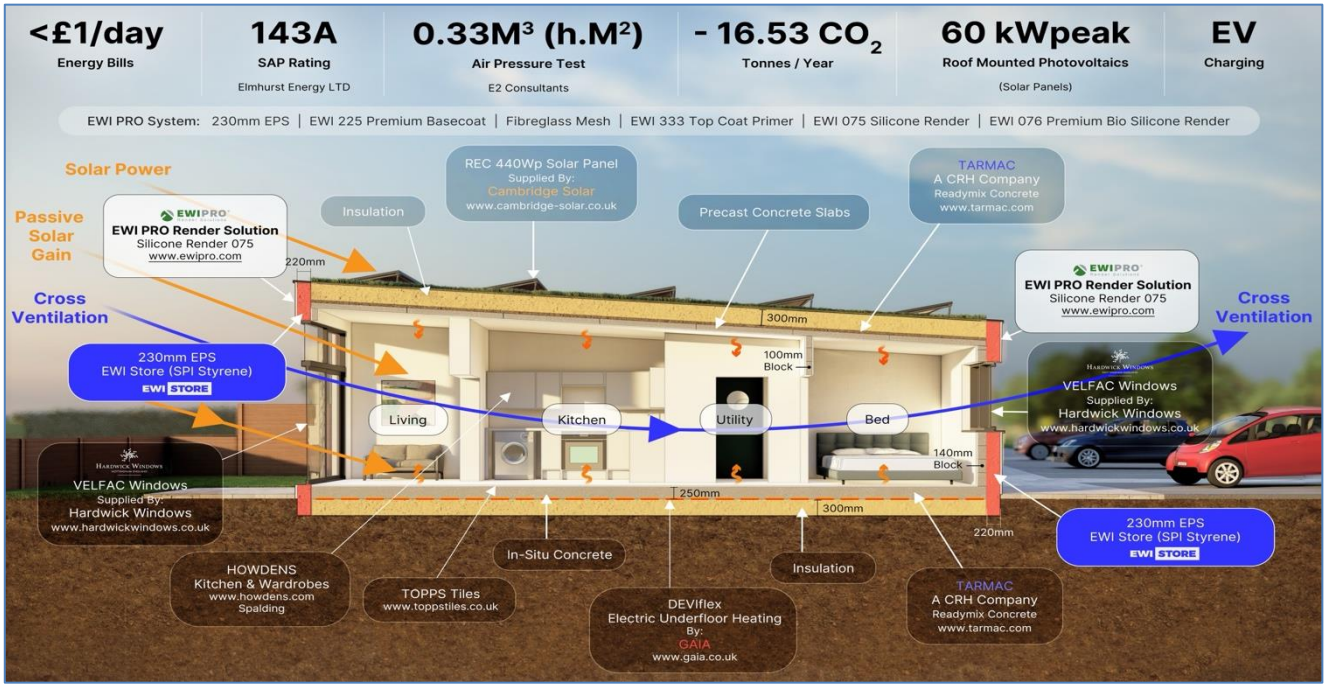

Figure 1: Typical Cross-Section of Howgate Close

DESIGN PRINCIPLES

The original project design was undertaken by the Hockerton Housing Project (HHP) using the design principles applied at HHP by its Architects, Professors Brenda and Robert Vale (The Vale's)
These design principles were first published in (The Vale's, 1975) book, 'The Autonomous House', and implemented at their former Southwell home, featured in another book (The Vale's, 2000) 'The New Autonomous House', the UK's first dwelling to export photovoltaic-generated renewable energy to the National Grid.
Intrinsic to the Howgate's performance, is the utilisation of Passive Solar Design (PSD) principles (Stirling, 1982); *southerly orientation, high thermal mass superstructure, super-insulated building envelope, triple glazing and roof mounted photovoltaics.* Other differentiating construction specifications include; solid external walls (no cavities) floating slab (no foundations) contiguous external insulated envelope (no cold bridging) externally located window and door jambs (improved Psi values) and hot water demand at source (no stored hot water)

BUILDING PERFORMANCE SPECIFICATION

Stable internal air temperatures of 23^0C (+/- 4^0C) have been recorded over the first 15months of occupation with little to no active heating. Variations in heating loads are due to occupational patterns, demographics and household numbers across the nine homes. Exceptionally low heating loads are achieved with the combination of PSD, high thermal mass superstructure (total thermal mass 152MJ/K, 1.16MJ/k/m^2) and an externally super-insulated fabric (average building U-Value 0.2W/m^2K) Very low fabric heat transmittance (U-Values) have been achieved; Roof -0.08W/m^2K, Floor – 0.07W/m^2K, Wall – 0.13W/m^2K. Air Pressure Tests as low as 0.66m^3@50Pascals were recorded.
A back-up heating system is provided by a low-grade electric under-floor heating system of 0.9KW/dwelling.

RESIDUAL HEAT RESERVOIR

Concomitant elements of low thermal bridge junctions, contiguous insulated envelope and high thermal superstructure optimise the buildings' residual heat reservoir (Harrall, 2023) This is a body of heat energy is retained within the building fabric. At Howgate an uninterrupted layer of 220mm (XPS) to 300mm (EPS) external insulation envelopes the buildings. Subsequently, sufficient heat is retained within the thermal mass to sustain elevated internal air temperatures of circa 23^0C.

PENDING PERFORMANCE STATISTICS

3D Psi calculations, Interstitial Condensation Calculations and a further 2months energy bills are anticipated to be included within the Full Paper.

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COST OPTIMAL ANALYSIS OF PEBS: STATUS QUO AND FUTURE PERSPECTIVES

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SUMMARY

This paper describes the cost optimal calculation method for the techno-economic assessment of Positive-Energy-Buildings (PEBs. The cost optimal calculation method is based on the EU supplementing guideline 2012/C 115/01 [1] and compares global costs and net primary energy demand of different technology packages. The analysis, carried out under the Horizon project EXCESS, also shows a cost optimal analysis of different technology packages of the four pilots of the EXCESS project. The results of the analysis reveals that not all PEB technologies reduce global costs with current energy prices. Results are very sensitive to calculation parameters such as electricity prices, discount rate and calculation period. Furthermore, results indicate that PV and a change of the heating system are in most cases cost-effective technology solutions that reduce net primary energy demand and global costs. However, a systematic view on cost of technologies is needed, as some technologies are not cost-efficient itself, but are enabling technologies that provide additional benefits can make the whole system more cost-effective.

INTRODUCTION

Positive Energy Buildings (PEBs) may be an integral part of comprehensive approaches towards sustainable urbanisation and decarbonisation of the European building stock, which is currently responsible for about 36% of all CO_2 emissions in Europe [2]. The proposed new Energy Performance of Buildings Directive (EPBD) revision requires Zero Emission standard for all new buildings after 2030 (2027 for public buildings) and a complete decarbonisation of the European building stock by 2050 [3]. On this line, the design of new PEBs and the refurbishment of existing buildings from a PEB perspective will become an important element for the decarbonisation of the economy in the next years.

The new construction of PEBs and the refurbishment according to PEB standard requires high initial investment costs, which will amortise to some extent over the entire lifetime of the building. An important question is to what extent and in which timeframe certain technology packages amortise. The main target of this paper is to develop a cost-optimal calculation methodology and explore technology packages for the transformation of reference renovations into PEBs through the application of this cost-optimal analysis of the four pilot projects of the Horizon2020 project EXCESS.

The demonstration cases are multi-storey residential buildings that are located in four different climate zones (Nordic, Continental, Oceanic and Mediterranean climate zone) to ensure high replicability across Europe. The pilot buildings include a new residential building (Helsinki) as well as existing buildings renovated according to the PEB standard (Hasselt, Graz and Valladolid).

COST-OPTIMAL METHODOLOGY

The methodological basis for the cost optimal analysis of technology packages to which this paper refers is the EU methodology framework 2012/C 115/01 [1] which is a supplementing guideline of the EU EPBD (2018/844/EU). The guideline establishes a comparative methodology framework for the calculation of cost-optimal levels of minimum energy performance requirements for buildings and building elements. The framework defines the calculation method of primary energy demand and global costs in terms of Net Present Value. The calculation of the global cost considers all initial investment costs and the Net Present Value of operation and maintainance costs. Furthermore the NPV of the annual energy costs as well as the NPV of revenues from renewable energy feed-in of the whole calculation period are considered in the global costs.

Net primary energy demand is defined as annual overall energy use in terms of primary energy. As for the analysis described in this report, the net energy demand parameter includes energy use for space heating and cooling, ventilation, DHW and lighting. Electricity for household appliances or plug loads are usually not included in net primary energy demand when the cost optimal calculation method is used. In the present work calculations are performed with and without plug loads in order to analyze the impact of plug loads caused by residents. Onsite renewable energy supply is also considered in the equation as a subtractive term as it reduces the net primary energy demand. It should be noted that primary energy means that the demand and supply of electricity and the demand of gas and district heating, is multiplied by the specific net Primary Energy Factor (PEF).

RESULTS AND CONCLUSION

The cost-optimal analysis in this paper highlighted the economic feasibility of achieving the Positive Energy Building (PEB) target for demo buildings in different climate zones. The analysis showed that not all PEB technologies are cost effective and reduce global costs. According to the analysis discussed in this paper, renewable energy production with PV can be considered as cost-effective technology, as global costs decrease with an increase in PV area with current electricity prices (~0.2€/kWh) and electricity selling prices (~0.1€/kWh). The shape of the building is a crucial parameter for the cost effective realization of a PEB. If there is little space for conventional PV, BiPV and PVT are key technologies for PEBs. However, BiPV and PVT are also more expensive than conventional PV.

The change from a gas heating system to a new heat pump system is cost effective as it reduces net primary energy demand and global costs. However, the profitability of such a change is very sensitive to electricity prices and gas prices. If it is assumed that gas prices will decrease below 0.1€/kWh, the high investment costs for a new heating system with aerothermal or geothermal heat pump cannot be offset by energy cost savings. Furthermore, it can be concluded that additional functionalities in the thermal heating system (such as deep boreholes and seasonal storage) increase global costs. The analysis showed that a geothermal heat pump with traditional 300m boreholes leads to lower global costs than the innovative thermal system with 600m deep boreholes, cooling system and thermal storage. The latter however provides a seasonal storage and a high level of flexibility to the energy system.

The cost effectiveness of PVT panels depends on the overall system. PVT decreases net primary energy demand but increases global costs with current available PVT costs in the pilot cases. The main cost driver for this technology is the complex installation of the panels. PVT has a high advantage if the roof is too small to provide sufficient PV energy to the building. Furthermore, it has to be mentioned that PVT can be part of broader solutions such as in the Finnish pilot case where it provides heat to be stored in the boreholes and thereby thermally regenerate the bedrock that serves as seasonal storage. In applications with low cooling demand in combination with a high heat energy demand and little available space for the collector, PVT is highly relevant for the efficient functioning of the thermal system. It can reduce the amount and depth of the boreholes and thereby reduce the drilling costs. This example shows that it is necessary to have a system view on costs. This shows that even if individual technologies may not be cost efficient, they can be enabling technologies that make the entire system

more cost efficient. Another example for the need of a systemic view on costs is the Austrian demo case that showed that a multifunctional façade element (wall heating, insulation, PV) as stand-alone technology is not yet a cost effective technology for the realization of a positive energy building with the current assumptions and calculation methodology. Additional benefits have to be taken into account (e.g. higher comfort, higher on-site self-sufficiency rate and thus lower energy cost in the neighborhood or potential flexibility revenues). This will make the multifunctional façade elements more favorable and profitable than a typical deep renovation.

The analysis also revealed that there are situations possible, especially in Southern Europe, where the PEB standard can be reached just with PV and without deep renovation measures as the PEB definition and the cost optimal framework do not distinguish between demand-side solutions (e.g. building envelope renovation) and RES-based active technologies and account over one year. Furthermore, the PEB definitions and the cost optimal analysis also do not explicitly consider seasonal minimum self-sufficiency rates in the calculation method which grades down all technologies that provide seasonal storage. It is recommended to solve such shortcomings with future revisions of European legislation and strategies (e.g. EPBD, EU cost optimal framework). Furthermore, additional benefits of PEBs that are not considered in the cost optimal methodology as for example increased comfort through cooling and ventilation should get higher attention as they may increase the value of properties.

Overall it can be said that several technologies increase global costs with current electricity prices (0.2€/kWh). A change from nZEB to PEB standard leads to higher investment costs and in most cases also to higher global costs according to the analysis in this paper. To support the realization of PEBs, either subsidies are needed to cover the additional costs that cannot be covered by energy cost savings or pricing of greenhouse gas emissions increase to make PEBs one of the key building concepts of the future.

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CONFERENCE TOPIC

Topic: Sustainable Renovation
Cross-cutting theme: Policies, Life Cycle Assessment, Finance and Business Models

ACKNOWLEDGMENT

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TOWARDS POSITIVE ENERGY DISTRICTS - DISTRICT INNSBRUCK CAMPAGNE

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SUMMARY

Positive energy district (PED) [1,2] are a vision to enable and foster the energy transition in the building sector. The integration of heat pumps (HP) in buildings and districts to achieve a net positive energy balance is crucial. Efficiency potentials of the electric and thermal energy of districts can be unlocked with the use of HPs. This refers to both, the upgrade of waste heat and simultaneous generation of different energy use in buildings (space heating, DHW, space cooling/dehumidification) and includes self-consumption of on-site renewable electricity generation. Using the example of the new district Innsbruck Campagne [3], HP integration options [4] as well as PV integration potentials are evaluated with respect to reaching a positive energy balance. Both simulation results as well as monitoring results are presented. The importance of very high building efficiency standards as well as well-designed and dimensioned systems to achieve a positive energy balance and to reduce the so-called winter gap is highlighted.

INTRODUCTION

The building sector plays in many countries a key role for CO2-emission reduction. IEA's Net Zero by 2050 Roadmap includes the goal of almost 70% of electricity generated by solar PV and Wind and 1.8 billion heat pumps for the operation and supply of buildings. Districts offer the potential for further performance increase by different building uses and load patterns which can offer synergies both on the electrical side and on the thermal side. Moreover, a combination of different buildings could create load patterns that might favourable for a high HP performance (e.g. simultaneous cooling and DHW or waste heat use). Heat pumps show high performance for nZEB application, but for larger buildings, it is still challenging to implement efficient heat pump systems and a plus energy balance is not possible because of the limited space for PV (in relation to the treated area). While high-performance technologies are widely developed, new concepts are required in order to further reduce CO_2 consumption in the next decades. Heat pump concepts for groups of buildings and districts in combination with renewable energies can notably contribute to CO2 emission reduction. For high-performance and plus energy districts, the buildings become net energy producers and thereby an active part of the energy systems. Heat pumps are a key technology on the district level for sector coupling to link the heating and cooling demands with electricity production and integrate renewable energies.

METHOD

With the urban development project "Campagne-Reichenau", a new city quarter is being created in the east of Innsbruck on an area of approx. 84 000 m². Approximately 1 100 new apartments, numerous local supply and service facilities as well as sports fields and a club building are planned. As part of the Smart Cities Demo program, the project "Smart City Campagne Areal Innsbruck" was developed, planned and built for block 1 with 4 multi-apartment buildings and a total of 307 apartments and 2500 m^2 of commercial space. Innovative energy supply and distribution concepts were developed in cooperation with the housing companies and ESCOs involved.

A simulation study for the entire Campagne area was carried out in the planning process for block 1 using a new simulation tool that allows to compare various types and combinations of heat generation systems (heat pump systems and/or district heating) [3]. The degree of centralization of the heat generation system and the type of

heat distribution system with different concepts were investigated and compared. The aim of the study was to find the best combinations in terms of energy and ecological environmental impact. Especially in low-energy or passive houses, hot water preparation often accounts for a higher contribution than the space heating of the building. The choice of a domestic hot water supply concept can have a very large impact on the overall system efficiency and the total energy consumption of a building. Centralized or decentralized systems with the associated temperature levels and heat generators have to be carefully designed to achieve the desired high efficiency.

A comprehensive monitoring campaign pays special attention to the hot water supply and in particular to the hot water distribution in order to provide in-depth knowledge about the various influencing variables as well as effects on the various sections of the hot water supply and distribution. The monitoring data is used to validate the simulation tool with the real data. Furthermore, tapping patterns will be derived (including simultaneity factors) as an important input for future heat pump system design and dimensioning.

RESULTS, DISCUSSION AND CONCLUSIONS

Exemplarily, the results of a simulation study on the PV potential of the roofs and the facades including the effect of (self-)shading are shown (Figure 1). Due to the limited roof space in relation to the treated area and the relevant self-shading in the dense block, the PV potential is limited. A net positive balance cannot be achieved without employing additional areas for PV production. The reduction of the electric energy demand by means of a very high building envelope quality and a very efficient heat generation and distribution system is crucial. First monitoring results show potential for further improvements.

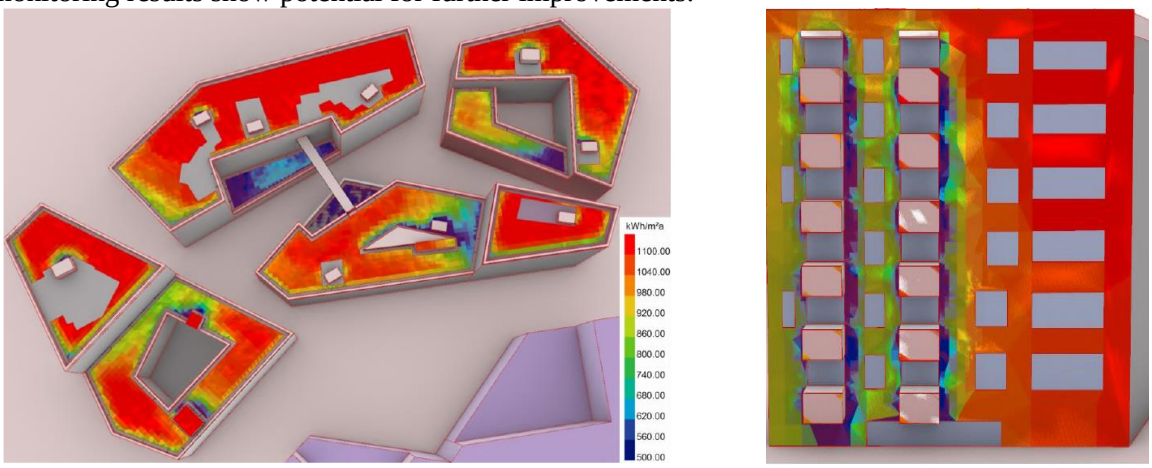

Figure 1: PV Potential on roofs and façade (example) [5]

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CONFERENCE TOPIC

Solutions for Energy Efficiency, Renewable heating and cooling, including high temperature applications, Future District Heating and Cooling Technologies

VALORISATION OF BIOGAS DIGESTATE THROUGH NUTRIENT RECOVERY BY MEANS OF MEMBRANE DISTILLATION - THE BIOPROFIT PROJECT

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Keywords: Digestate processing, membrane distillation process, nitrogen recycling from digestate, humus substrates, CO2 certificates from humus production

SUMMARY

Biogas plants produce considerable quantities of digestate as a by-product, the great ecological utilisation potential of which was researched as part of the ACR project "BioProfit". The specific aim was a resource-efficient valorisation of the "biogenic residue digestate" in the form of a new marketable liquid nitrogen fertiliser and a peat substitute and/or humus substrate to improve soil health. The carbon stored in the humus is removed from the CO_2 cycle, allowing agriculture to earn CO_2 emission certificates.

INTRODUCTION

The status quo: The most common use of digestate is still its direct application to agricultural land, as it is considered a very good fertiliser due to its high nutrient content, but with the disadvantage that nutrients dissolved in the digestate slurry can easily be washed out and some of them can also get into the groundwater. In addition, direct application does not result in long-term carbon fixation in the soil. The carbon contained in the digestate is quickly lost to the atmosphere.
The developed solution concept for biogas digestate valorisation:
Mechanical separation of the fermentation residue and separate further processing of the liquid and solid fractions are prerequisites for upgrading or further utilisation of the fermentation residue. The solid fraction contains a large proportion of the plant-available fertiliser and carbon, while the liquid fraction is particularly rich in nitrogen.

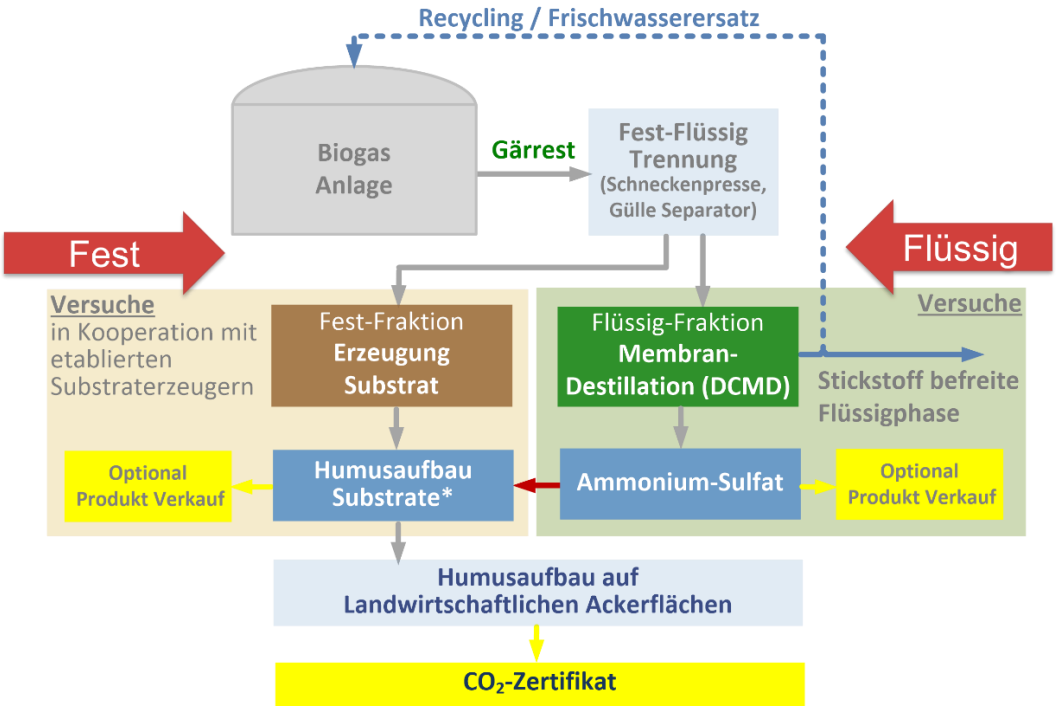

Fig. 1: Visualization of the developed solution concept (AEE INTEC)

New treatment options for the liquid fermentation residue fraction - nitrogen recycling using the ISOTHERME DIRECT CONTACT MEMBRANDESTILLATION PROCESS (isoDCMD):
Conventional membrane processes such as reverse osmosis or ultrafiltration have only proved to be economically viable for a few farms due to high operating costs (energy costs for electricity, costs for digestate pre-treatment, use of flocculants).
The isoDCMD is based on membrane contactors and can be seen as an innovative "key enabling technology" for separating and recovering nitrogen from fermentation residues. The driving force of the isoDCMD process is a vapour pressure difference, which in this case is not induced by a temperature difference (as in the conventional direct contact membrane distillation process), but only by the vapour pressure of the NH_3 (from the dissociation equilibrium depending on temperature and pH value) in the feed and the binding (vapour pressure = zero) of NH_3 as an ammonium salt on the permeate side.

This means that efficient evaporation is largely decoupled from the evaporation temperature and enables more selective removal of ammonium in the form of ammonia (NH_3) even at low temperatures (25-40°C) as well as the combined utilisation of low-temperature waste heat, which is usually available free of charge. As this is a distillation process and the process is not pressure-driven (no blocking of the membrane pores), it places only low demands on the pre-treatment of the fermentation residue. Only mechanical solid/liquid separation of the fermentation residue is required; the use of chemicals or expensive flocculants can be completely dispensed with.

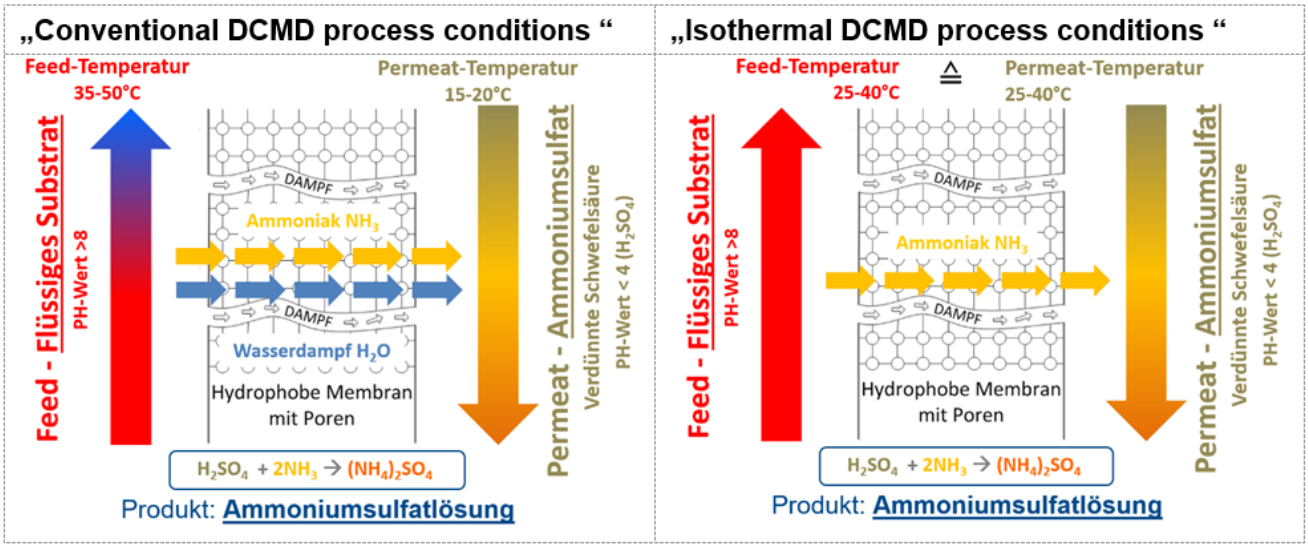

Fig. 1: Nitrogen separation using the DCMD process and production of a liquid nitrogen fertiliser, left: conventional DCMD process, right: the newly developed isothermal DCMD process (AEE INEC)

Another aim was to identify and evaluate new treatment and utilisation methods for the separated solid fraction. The solid fraction is still very rich in carbon and can, for example, be used specifically as a humus building substrate to build up new soil humus on agricultural land and sustainably improve soil fertility. Targeted humus formation can also fix significant amounts of CO_2 in the soil. One tonne of soil humus binds around 2 tonnes of CO_2.

A calculation basis for the certification of measures to save greenhouse gases through humus build-up was created and the potential for agriculture to obtain CO_2 emission certificates from humus build-up measures was determined.

CONCLUSIONS

In continuous operation (24/7) with the pilot plant on a container scale, it could be shown that even at a very low operating temperature of only 27°C at a pH value of 8.7, up to 98% of the N-NH_{4+} can be separated from the liquid fraction with the isoDCMD. The nitrogen-free liquid can thus be fed back into the biogas plant as recycled water and freshwater substitute without any negative consequences (nitrogen inhibition). The ammonium sulphate solution (ASL) produced currently has a concentration of around 62 g/l (N-NH4+ of 13g/l). Trials are currently underway to further optimise the ASL product concentration.

The starting point for determining the CO_2 potential was a comprehensive analysis of the chemical composition of the fermentation residue solid fractions from different biogas plants and the humus substrates developed. Based on the carbon and nitrogen content, the respective humus formation potential and the realisable carbon dioxide equivalents or CO_2 emission certificates were evaluated by means of a mathematical/model-based analysis.

CONFERENCE TOPIC

Centres for circularity, New technologies for realizing energy and resource efficiency,

USING HYDROGEN TO DECARBONIZE THE BRICK AND TILE INDUSTRY

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SUMMARY

For a significant reduction of carbon dioxide (CO_2) emissions, it is assumed that hydrogen (H_2) will substitute natural gas in the upcoming years. Therefore, the application limits of existing burner technology must be evaluated with increasing H_2 content in natural gas. To investigate the H_2-readiness of typical burners, numerical simulations and experimental investigations were carried out in lab- and industry scale, in test facilities and at a tunnel kiln system in the brick and tile industry. The results of the examination of the existing conventional burner for natural gas and an additive manufactured dual-fuel burner for natural gas will be presented for natural gas/ hydrogen operation. The investigations carried out so far suggest that it is possible to use H_2 or in addition to natural gas as a fuel gas in tunnel kiln systems in the brick and tile industry. Ongoing investigations by means of simulation and measurements on the industrial furnace will provide further insights into this.
Keywords: Decarbonisation, burner technology, hydrogen, tunnel kiln, brick and tile industry, CO_2-reduction

INTRODUCTION

The main energy sources used for the production process of bricks are gas and electricity. From an energy point of view, numerous optimizations of the tunnel kiln process have been carried out in the past decades, which have led to a significant increase in energy efficiency. With the Roadmap of the Brick and Tile Industry (Geres et al., 2021) and the legal requirements, these demands are further tightened in order to achieve a climate-neutral production of the brick and tile industry by 2050, respectively 2045. The reduction or avoidance of CO_2 emissions from fossil fuels can only be achieved by substitution with renewable gases. In this context, the use of "green" H_2 is at the focus of the discussions.

In brick and tile production, the tunnel kiln is the most advanced technology. Figure 1 shows an illustration of a typical tunnel kiln. Cars with green bricks (clay products/bricks before being fired) enter the kiln on the left site and pass through the preheating, firing and cooling zones, each with a predefined temperature. Gas and bricks move through the kiln in counter current. Cold air enters the kiln from the exit of the cars, cools the fired bricks and is thus heated. After passing the firing zone, the hot flue gases flow through the preheating zone to the entry of the cars and thereby transfer heat to the green bricks entering the kiln. During firing in the tunnel kiln, numerous reactions and processes take place. These processes lead to a solidification of the raw material and finally to fired bricks. The arrangement and operation of the burners is designed to achieve uniform temperature distribution and heating of the densely packed bricks. Typically, high-speed burners and lance burners with a high outlet momentum are used in the brick and tile industry. These burners create a turbulent circulating flow between the stacks of bricks which leads to a good heat transfer.

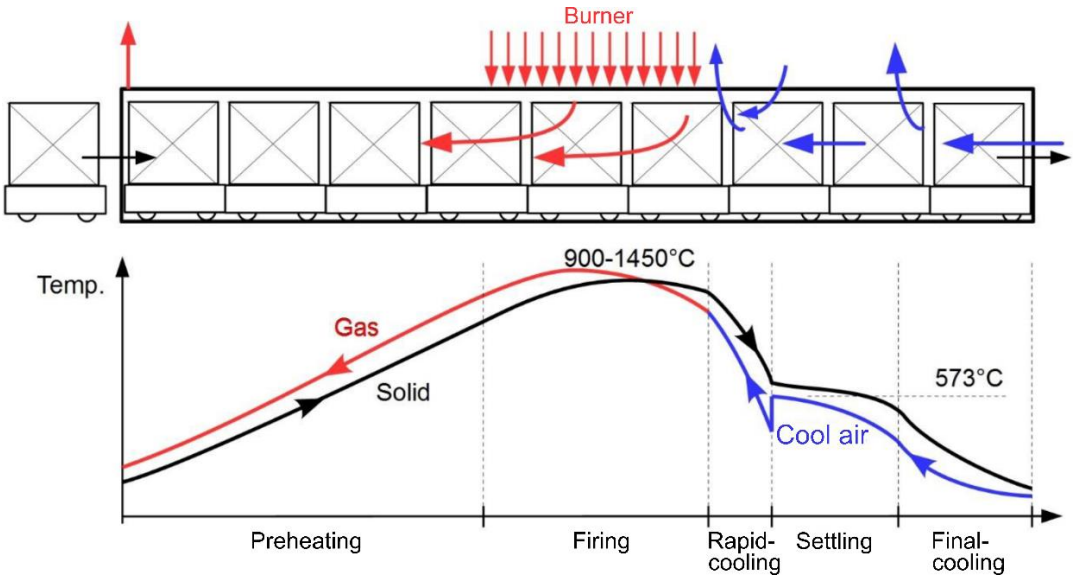

Fig. 1: Illustration of a tunnel oven with temperature profile of the process

Since H_2 will continue to be in limited supply for the next few years, it is important to be able to react flexibly to the supply situation. To ensure the required flexibility, a new burner concept with a separate gas supply for natural gas and H_2 was developed by Kueppers Solutions. This concept allows the use of the pure gases as well as their mixing directly inside the burner. The dual fuel mixing unit developed for this purpose ensures optimum mixing and flow control of the fuel gas with the combustion air. This in turn leads to efficient combustion and low pollutant concentrations in the exhaust gas. Natural gas and H_2 differ in their material properties and combustion behaviour. Especially the differences in density, required volume flows and flow velocities as well as the flame stabilization behaviour of the two gases are challenging for the design of a dual fuel burner. The mixing unit has been designed to consider the properties of natural gas and H_2 and to produce a comparable flame independent of the fuel gas. Important for the brick and tile industry is to understand how the fuels such as H_2 or blends of natural gas and H_2 affect product quality and the emission of pollutants. An important quality criterion, especially for bricks and roof tiles, is the visual appearance, which is influenced by the kiln atmospheres.

This paper presents the results of tests on a conventional natural gas burner and on the recently developed dual fuel burner. Experimental results and Simulations for operation with natural gas, H_2 and with a blend of natural gas and H_2 are discussed and compared. Complementary simulations of the brick kiln are performed to understand the flow topologies in the kiln and the influence of the burner flow. This can also provide an insight into the temperature distribution in the kiln. Tests with natural gas, H_2 and blends of natural gas and H_2 were carried out on laboratory kilns with downscaled burners in order to prove the function of the new burner and to be able to evaluate the effects of the combustion gas on product features. Finally, tests were carried out on an industrial kiln which had previously been equipped with the new burners.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:
Renewable heating and cooling, including high temperature applications

REVERSE POWER PLANTS: COMBINED HEAT AND POWER WITH NEGATIVE EMISSIONS

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SUMMARY

Global climate change is one of the greatest challenges of our time. Urgent action is required to meet the 1.5-degree target set at the 2015 UN Climate Change Conference in Paris. Measures to reduce emissions are no longer sufficient. Carbon sink solutions facilitate the storage of carbon dioxide, preventing it from accumulating in the atmosphere. SYNCRAFT is an innovative Austrian company that builds Combined Heat and Power plants (CHP) using wood biomass as fuel. SYNCRAFT's plants not only produce heat and power from renewable energy sources. They also capture and store carbon dioxide using Negative Emission Technologies like Biochar Carbon Removal as well as BECCS (Bioenergy with Carbon Capture and Storage). This pioneering concept is climate positive and significantly contributes to CO_2 reduction and negative emissions (Carbon Dioxide Removal).

HEAT AND POWER FROM BIOMASS

The prevalent global energy crisis has spurred growth in the renewable energy sector. Bioenergy amounted to 12% of all renewable energy sources in global gross energy consumption in 2019 and is expected to continue to grow in the next years (see WBA, 2021). In Austria, the share of bioenergy within the renewable energy segment is considerably higher at 55% of gross domestic consumption (ABA, 2023). Globally, biomass is the largest renewable energy source and comes from agriculture, forestry, and residual materials. Biomass is a climate neutral energy source. It is highly versatile and can be provided as a solid, liquid, or gaseous energy source for generating heat and power. Biomass is non-volatile, always available, and flexible in use. As a limited resource in regional energy supply systems, it has to be supplemented by other energy sources to meet consumption demands. Bioenergy produced in a resource-efficient and sustainable way can make a valuable contribution to securing energy supply.

SYNCRAFT COMPANY

SYNCRAFT is a Greentech company based in Schwaz, Austria. It was founded in 2009 as a spin-off of the MCI Entrepreneurial School Innsbruck. Its team of over 50 employees is dedicated to a common goal: combating climate change. SYNCRAFT builds Combined Heat and Power plants (CHP) that are designed to produce both heat and electricity for district and industrial heating. Their Reverse Power Plants feature a patented floating fixed-bed gasifier and convert forest residues into heat and power. As a third product, the plants produce biochar. If applied as soil substrate, feed additive, or in other industrial applications, such as construction materials or climate concrete, biochar constitutes a Negative Emission Technology (NET) based on a Biochar Carbon Removal (BCR) process.

REVERSE POWER PLANTS

SYNCRAFT Reverse Power Plants work in reverse mode to traditional coal-fired power plants, where fossil raw materials are mined and burned in order to generate energy. Burning coal emits large quantities of CO_2, which increases the anthropogenic greenhouse effect. In Reverse Power Plants, forest residues are processed in a resource-efficient and sustainable way to generate bioenergy and heat. As a third product, the plants produce biochar, which has the capacity to store 30% of the CO_2, which is originally stored in the tree (which, if rotted, would be released back into the atmosphere). SYNCRAFT power plants offer a decentralized power range

between 400 and 4,000 kW. They constitute the first energy system that generates climate positive power and heat in combination with EBC-certified biochar on an industrial, commercial scale. SYNCRAFT's Reverse Power Plants have an electrical efficiency comparable to 100 MW+ power plants. Their heat performance rate is 1.4, with no dust emissions and residues during operation and without additional auxiliary materials.

SYNCRAFT TECHNOLOGY & DEVELOPMENTS

In 2007, a small team of process engineers successfully developed a floating fixed-bed gasifier, a revolutionary process for generating electricity and heat from biomass. In the first stage of this process, wood is dried to less than 10% water content using the low-temperature heat recovered from cooling the product gas. In the following two-step gas extraction phase, the biomass is broken down through pyrolysis into its constituent parts to produce solids and gas and then gasified in the downstream reduction zone. The gas, cooled to around 750°C, exits the top of the reactor and is separated from the biochar. It then is cooled to about 100° C, and the extracted heat is fed into a heating network. Once the gas has been cooled again to between 25°C and 30°C, it has reached the required temperature for generating electricity in high-efficiency wood gas engines.
Upon further research into biochar and its Negative Emission Technology (NET) potential, the patented exhaust gas condensation technology was developed, unlocking another 20% heat availability. This additional heat is used to dry the wood chips, thus raising the overall efficiency of wood power plants to over 90%.

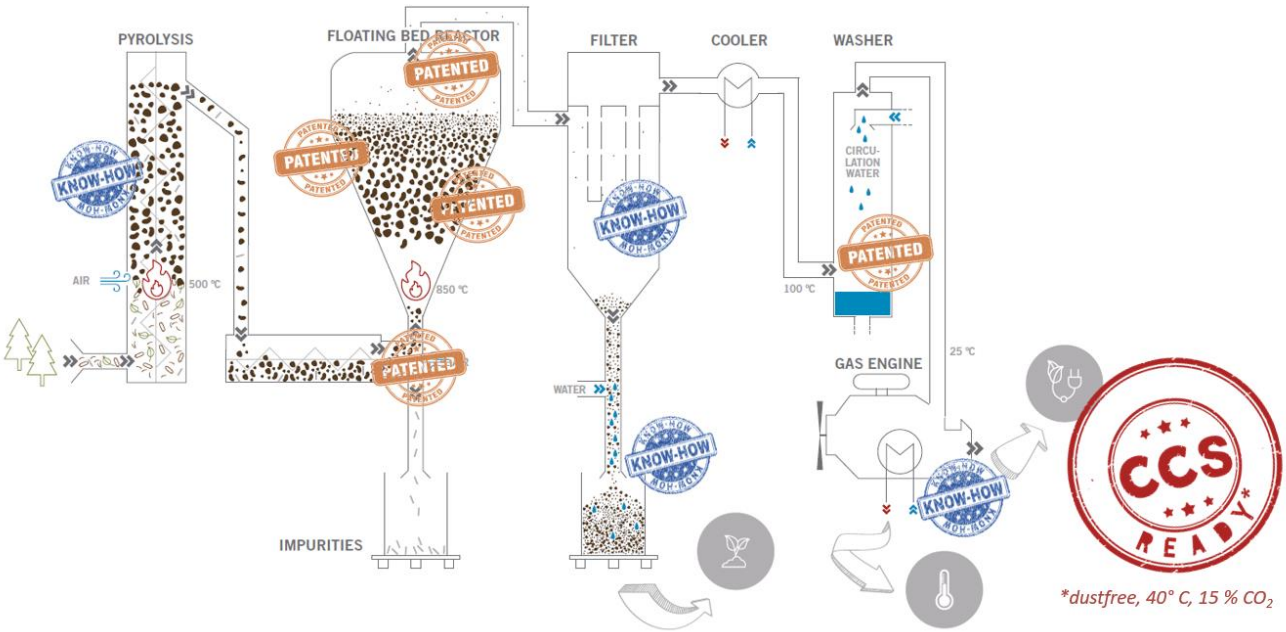

Fig. 1: SYNCRAFT technology, patented floating fixed bed reactor, and patented exhaust gas condensation.

REVERSE POWER PLANTS WITH BIOCHAR & BECCS

Biochar Carbon Removal (BCR) is considered an effective method to counter carbon dioxide emissions. As a resource, biochar is currently viewed as one of the key Negative Emission Technologies (NET). It can be implemented in a relatively short time and can be scaled up to considerable quantities. Biochar is chemically inert. This means it doesn't readily interact with substances, which makes it very stable and resistant to chemical breakdowns. In its natural form, inertinite is a highly stable carbon found in the lithosphere of the earth's crust derived from biomass over millions of years. In Reverse Power Plants, biochar is produced at a temperature of 850°C. Organic geochemists have found that natural biochar formed at temperatures over 550°C predominantly exhibits Ro (random reflectance) ranges well above IBRo2%, characterizing it as pure inertinite maceral (Sinai et al., 2023). With an average reflectance of almost 4%, SYNCRAFT generated biochar is among the most stable forms of carbon currently existing.

The company recently implemented a third innovative technology that allows it to capture biogenic CO_2 from the flue gases emitted during power generation. This high-purity carbon dioxide (CO_2) can be used for food and beverages and thus replace the use of CO_2 from fossil sources (Carbon Capture and Utilization, CCU). Integrating this technology in Reverse Power Plants allows SYNCRAFT to capture 30% of the CO_2 via BCR and to utilize an additional 56% as biogenic CO_2 (E290). This means that only 14% of the CO2 initially stored in the wood biomass is released back into the atmosphere.
SYNCRAFT's vision is to take bioenergy production to the next level by generating biochar and biogenic CO2 from sustainable forestry for numerous applications such as green carbon, green soda, and climate concrete.

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Figure 1. SYNCRAFT technology, patented floating fixed bed reactor, and patented exhaust gas condensation.

CONFERENCE TOPIC

- Renewable Heating and Cooling, Including High Temperature Applications
- Solutions for Energy Efficiency
- Approaches Towards Net-Zero/Negative Emissions in the Industry Including CCU
- Future District Heating and Cooling Technologies

THERMOCHEMICAL REACTIONS TO ENABLE ADAPTIVE BUILDING INSULATION AND THERMAL COMPONENT ACTIVATION

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SUMMARY

The thermal activation of existing building masses can substantially enhance the energy efficiency of buildings by utilizing them as thermal energy storage. To accomplish this, it's crucial to manage the heat transfer across the large components like walls or ceilings. This can be realized by applying a controllable insulation layer, which merges the gas pressure-dependent thermal conductivity of porous structures with reversible gas-solid-reactions. The heat transfer mechanism in porous insulation materials is primarily influenced by the Knudsen effect, which characterizes the S-shaped thermal conductivity based on the prevailing gas pressure in the insulation panel. By using thermochemical materials, the gas pressure in the vacuum insulation panel can be accurately regulated along the equilibrium line by modifying the reaction temperature. This facilitates precise control of the heat flux through the insulation panel and allows the thermal activation of building masses. The thermochemical reactor is a crucial component in the comprehensive adaptive insulation system. The contribution will present a new reactor concept that addresses the key challenges of precise pressure adjustment, system dynamics, and energy efficiency and furthermore the experimental integration of the reactor in a lab-scale controllable insulation system will be shown.

INTRODUCTION

According to the 2020 Global Status Report of the United Nations Environment Programme (Henry, Prasher, & Madumdar, 2020), the building and buildings construction sector collectively contribute to more than one-third of global final energy consumption and nearly 40% of the total direct and indirect CO2 emissions. There is clearly a significant potential for innovative and resource-efficient thermal management for buildings. Traditional insulation materials offer low – but constant – values of thermal conductivity and thus play a significant but only passive role for the heat flows in buildings. However, if insulating materials could be made variable in their thermal transmittance, heat flows could be adapted to changing internal (heating/cooling comfort, number of people and electronic devices, etc.) and external (seasons, weather, day/night cycles, etc.) conditions, and further, building components could be made active components of the energy system.

Firstly, adaptive building envelopes are capable of contributing to significant energy savings, according to a referred study in a comment (United Nations Environment Programme, 2020) in Nature Energy, which declares variable conductance buildings envelopes to be one of the five grand challenges for decarbonization. This would allow solar heat to be gained temporally and partially in winter and transitional seasons as needed. Most importantly, variable conductance building envelopes can reduce the energy consumption of air-conditioning in non-residential buildings by taking advantage of the passive cooling effect by night during hot summer periods – at least in mid-latitudes.

Another scenario for controllable insulation in buildings is the utilization of existing high-capacity building components as thermal energy storage and thereby transforming buildings into active players for grid flexibility. Provided the heat flux through an insulation layer can be controlled in terms of time and amplitude, thus thermally activated components, charged by surplus energy, are able to contribute to space heating/cooling and peak shaving. Such a controllable insulation can be realized by combining the gas pressure dependent thermal

conductivity of porous structures with reversible gas-solid-reactions. The thermal conductivity of porous media is highly dependent on the prevailing gas pressure, the relation follows an S-shaped curve (Knudsen effect). On the other hand, the gas pressure of thermochemical gas-solid-reactions can be controlled by setting the temperature of the reaction system – along the equilibrium line. By connecting these two correlations, the gas pressure in an insulation layer can be specifically adjusted and thus the heat flux through the insulation can be controlled.

The thermal conductivity of porous insulation materials is determined by the Knudsen effect, which causes an S-shaped relationship between the thermal conductivity and the gas pressure in the insulation panel. In this system, a vacuum insulation panel is linked to a reversible metal hydride reaction system. By adjusting the temperature of the metal hydride, the endo-/exothermal reaction can be controlled, and the corresponding pressure can be set along the equilibrium line of the thermochemical material. The two core components of the integral adaptive insulation system are the enveloped porous vacuum insulation panel and the metal hydride reactor. These units are physically linked, meaning that the temperature setting of the metal hydride is directly related to the gas pressure and, as a result, to the thermal conductivity of the insulation panel.

At DLR, we employ metal hydrides/hydrogen as thermochemical reaction system for the gas pressure adjustment. Our controllable insulation system is based on two individual core components – connected via valve - that correspond to the respective physical/chemical effects: a controlling thermochemical reactor and an open-pored vacuum insulation panel. This means the metal hydride material is not integrated into the panel, but a separate reactor is used, which serves as an independent control unit for the reversible gas pressure adjustment. The schematic approach can be seen in Fig. 4.

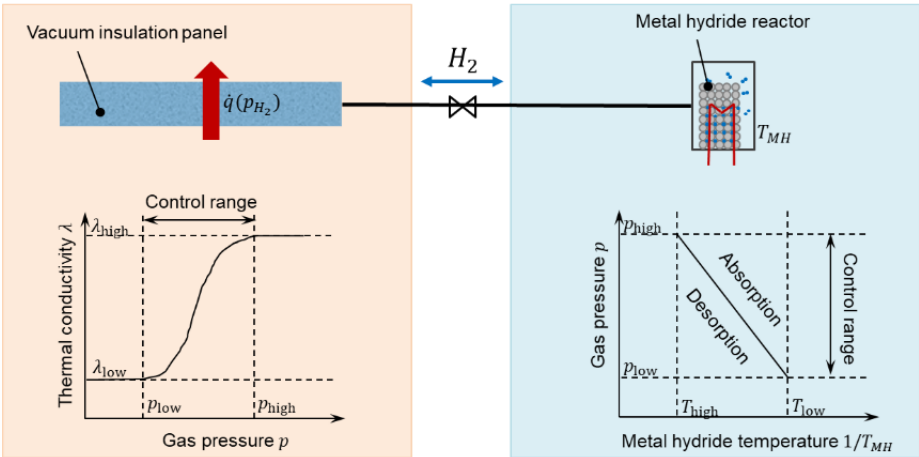

Fig. 4: Representation of the concept and fundamentals of the controllable thermal barrier, with the depicted Knudsen effect (left) and the Van't Hoff equilibrium plot of thermochemical materials (right).

THERMOCHEMICAL GAS CONTROL UNIT

The reactor component governs the controllability of the gas pressure in the porous insulation material and thus the heat flux. The operation range of the gas pressure adjustment range according to the set temperatures directly corresponding to the employed metal hydride material. Important characteristics of the overall insulation system as controlling sensitivity, dynamic behavior as well as energy consumption for varying the heat flux strongly depends on the reactor component. On the one hand, the selection of suitable metal hydride materials and the accurate characterization of them in vacuum is relevant to precisely adjust the gas pressure based on setting the temperature of the thermochemical reaction system. On the other hand, a well-developed reactor concept as container for the metal hydride material is needed to technically provide the required hydrogen pressure in the connected insulation panel fast, reliably and with low energy consumption.

At DLR, we have developed a novel approach designing the reactor component that focuses on the dynamics as well as the energy efficiency of the reactor itself. The reactor meets all technical requirements (strength and

tightness in vacuum, temperature resistance in the given temperature range, connectivity on the gas side to the insulation panel, etc.), and has two essentially new features. Firstly, the temperature control of the metal hydride material is implemented via thermoelectric modules, which enables active electrical heating or cooling. And secondly, the reaction material is mostly thermally detached from the reactor housing. As a result, the temperature-loaded mass can be reduced and, accordingly, the energy losses within the passive reactor mass can be significantly decreased due to lowered temperature changes there during operation.

We were able to realize this concept by building a prototype reactor and carry out various functional and characterization tests. Both the idea of the thermal decoupling of reaction material and reactor housing as well as the specific thermoelectric temperature management of the metal hydride is demonstrated. The reactor made it possible to increase the hydrogen pressure from about 1 to 1000 mbar in less than 8 minutes, and vice versa from about 1000 to 1 mbar in less than 30 minutes.

The tested prototype of the gas pressure control unit has been connected to different insulation panels in a modular test bench and its functionality has been tested in combination. The conference presentation will show experimental data of the gas pressure control unit as well as the integral insulation system investigation regarding dynamic and thermal behavior at different gas pressures.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:
Renewable heating and cooling, including high temperature applications.

SOLAR REACTOR FOR SOLAR FUEL PRODUCTION – OPTIMIZATION VIA PROCESS INTENSIFICATION

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SUMMARY

The escalating global demand for energy, primarily met by finite fossil carbon sources, has led to unsustainable greenhouse gas emissions. In response, there is a growing focus on solar fuels for renewable energy production, with solar reactors playing a crucial role in synthesizing fuels through photocatalytic or photoelectrochemical processes. Solar fuels, like hydrogen and hydrocarbons, address the intermittent nature of solar energy by providing storage capabilities. This paper outlines a methodology for applying a process intensification approach in developing solar reactors, involving the pre-screening of waste streams, a process design based on degradation targets and solar fuel yields, and construction/testing of the reactor under artificial and real irradiation conditions. The proposed solar reactor design integrates a concentrating solar collector tube with a process intensification approach, aiming to increase solar fuel yields and achieve degradation of pollutants in input (waste) streams.

BACKGROUND ON SOLAR FUELS PRODUCTION THROUGH SOLAR REACTORS

The widespread utilization of fossil carbon, predominantly sourced from coal, crude oil, and natural gas, remains a cornerstone of global energy production, satisfying approximately 80,2% [1] of the world's energy demand. However, this reliance on fossil carbon, especially in industrial production and transport, has led to a concerning increase in greenhouse gas emissions, exacerbating climate change. Despite meeting current needs, these fossil carbon sources are finite. With escalating global energy demands, their continued usage is unsustainable and incompatible with efforts to limit the progressing global warming.

Within this framework, the global pursuit of sustainable energy sources has led to an increased focus on solar fuels as a promising avenue for renewable energy production. Solar reactors play a pivotal role in harnessing solar energy to synthesize fuels through, for instance, photocatalytic (PC) or photoelectrochemical (PEC) processes. Both processes induce a photoreaction by using solar irradiation in the presence of a catalyst. Unlike direct solar electricity generation through photovoltaic cells, solar fuels are synthesized substances that can be stored and used as energy carriers for different applications, such as transportation and power generation. The essential advantage of solar fuels lies in their potential to address the intermittent nature of solar energy by providing a means for energy storage and on-demand release.

Common types of solar fuels include hydrogen (H_2) or hydrocarbons like methane (CH_4) or even ethane (C_2H_6). The production of solar fuels typically involves the use of solar reactors. These reactors utilize sunlight as a direct heat source to drive chemical reactions. One widely studied method is solar water splitting – sunlight (photons) splits water into hydrogen and oxygen. To increase the process efficiency of water splitting, there is also a trend to use wastewater instead of pure water for H_2 production. Another potential approach involves the conversion of carbon dioxide (CO_2) into CH_4 or even C_{2+} products like C_2H_6 using solar energy, serving as a potential CCU (Carbon Capture Utilization) strategy.

In both approaches, research efforts focus on improving solar fuel production technologies' efficiency, scalability, and economic viability, emphasizing innovative reactor designs, advanced materials, and process intensification approaches. The goal is to establish solar fuels efficiently, with increased yield and purity, as a reliable and environmentally friendly energy source that complements other renewable energy technologies in the global transition toward a more sustainable energy landscape.

METHODOLOGY ON SOLAR REACTOR DESIGN

Within the development of the solar reactors towards the production of solar fuel, the methodological approach includes a pre-screening of different waste streams (industrial, municipal) based on the literature available and their analysis in terms of pollutants/resistant substances, concentrations, and general parameters (e.g., amounts, compliance with waste stream regulations), potentially being used in PC and PEC. Based on defined degradation targets for the diverse substances from different industries and fuel production, a process design for the reactor is developed, combining different approaches towards optimizing specific fuel generation (catalyst, light intensity, photo reactor design, sacrificial agents, optimum operating parameters like temperature, pH). Based on the design the solar reactor is constructed and tested at optimum rheological properties, at artificial and real irradiation conditions. Performance parameters like product yield (kg/m^2-h), Solar-to-Hydrogen efficiencies (STH %) and degradation of pollutants (concentrations, COD, etc. in mg/L) are measured.

INTENSIFIED SOLAR REACTOR CONCEPT TOWARD SOLAR FUEL PRODUCTION

To intensify solar fuel production based on PC and PEC processes in solar reactors for increased efficiency of the overall process, a design for solar reactors is proposed, that bundles competences from solar collector development, efficient reactor systems, catalytic material research, waste streams chemistry and the innovative production of alternative fuels.

In the design of the solar reactor, a PEC or PC process is integrated into a concentrating solar collector tube with optimized rheology through a targeted process intensification approach. A concave trough mirror surrounds the solar collector tube to concentrate the solar irradiation. The photo process is used to split water, waste water, or CO_2 by directly utilizing sunlight to produce alternative fuels such as H_2 or hydrocarbons like CH_4 or C_{2+} products. In the case of water splitting, the process efficiency can be increased by using wastewater - compared to pure water - as pollutants and contaminants serve as sacrificial agents. The advantage - at the same time as the fuel is produced, a significant elimination of pollutants and thus wastewater purification is approached. By combining this process concept with the direct use of solar energy, it is possible to offer the degradation components sufficient residence time in the reactor with simultaneous intensive energy and mass transfer, and thus good penetration of the radiation into the reaction tubes. Within the described approaches, the new designed solar reactor includes:

- the proof of concept of a solar reactor with a new rheology, through its design, construction, and operation
- an increase in solar fuel yields and
- purifying waste streams by at the same degrading pollutants and through this reaching degradation rates of > 50%

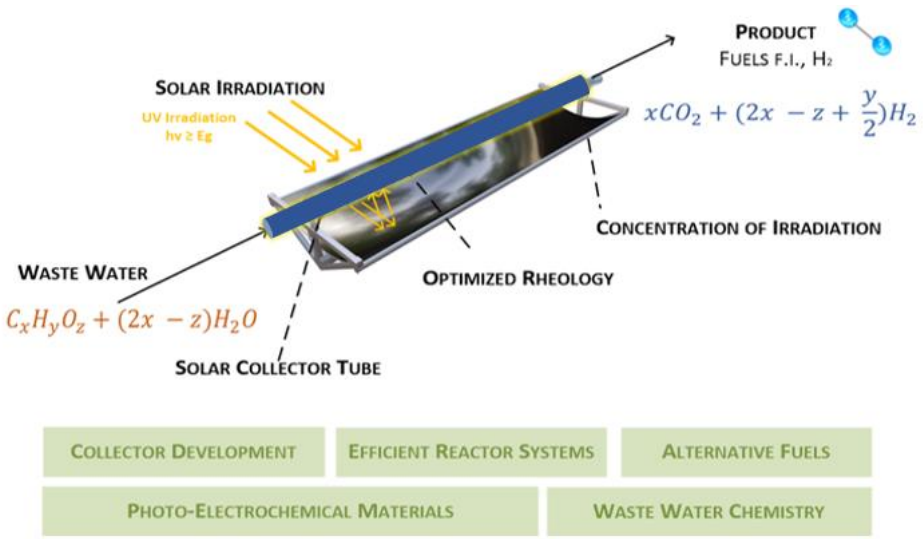

Fig. 1: Concept of the solar reactor

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CONFERENCE TOPIC

This abstract refers to the topics of:

- New technologies for realizing energy and resource efficiency (Process Intensification)
- Approaches towards net-zero/negative emissions in the industry including CCU

IMPROVING ENERGY EFFICIENCY OF CARBON CAPTURE PROCESSES WITH HEAT PUMPS

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SUMMARY

Carbon capture based on chemical absorption in amine-based solvents is the most relevant technology option to reduce CO_2 emissions from hard-to-abate industrial CO_2 sources and power plants. Because of the energy consumption of the carbon capture process, which is mainly attributed to heating the desorber, carbon capture has a negative impact on the efficiency of the process where CO_2 is removed. Heat pumps allow for heat recovery and provide high temperature process heat. Due to recent developments, heat pumps are now capable to supply steam and to provide high temperatures enabling new applications. This contribution investigates the integration of heat pumps into the carbon capture process of a furnace for steel processing to determine the most suitable heat sources and sinks and the achievable energy savings.

Key words: Heat integration, high temperature heat pumps

HEAT INTEGRATION FOR CARBON CAPTURE PROCESSES

Carbon capture technologies are an important element of the future energy system to lower CO_2 emissions to the excepted levels to comply with the climate targets. In 2022, 40 Mt CO_2 were captured all over the world. According to IEA's World Energy Outlook 2023, continuous growth is expected for CCUS. In the Stated Policy Scenario STEPS, 115 Mt CO_2 have to be captured in 2030 and about 500 Mt CO_2 in 2050. In the most ambition scenario, the Net Zero Emission NZE, the volumes of captured CO_2 increase considerably to 1 Gt CO_2 by 2030 and 6 Gt CO_2 by 2050. About half of the CO_2 emissions come from industry and from power generation. (IEA, 2023) Most commonly, chemical absorption of CO_2 is applied using amine-based solvents. The process is carried out in two columns, one for absorption and the other for desorption, where the CO_2 is released, and the solvent is regenerated. (IEA, 2020). The desorption step requires energy and is carried out at a higher temperature. Already in the IPCC report in 2005, optimization potential for future cost reductions was pointed out to reduce the energy requirements for capture. At that time, the cost for electricity production from natural gas combined cycle was increased by 35-70% by carbon capture. (IPCC, 2005). Studies on process modifications focus on absorption enhancement, heat integration and heat pumps, which are mainly mechanical vapor recompression systems (Le Moullec et al., 2014). Li et al. (2022) and Nyugen and Wong (2021) analysed the integration of mechanical vapor recompression in the desorber lowering energy consumption by up to 25%, but also mentioned the risk of corrosion and degradation when integrating compressors directly into the process.
In the last decade, the operating range of heat pumps has been significantly expanded towards high temperatures. They are on the verge of commercialisation and enable waste heat recovery and heat integration for new applications. In the range of 100-140 °C, there are already first of their kind commercial applications in the paper, food and chemical industry. Up to 160 °C, there are pre-commercial demonstrations, e.g. in drying processes and for steam production. Up to 200 °C, special refrigerants and compressors are needed, which are still in prototype stage, except for the use of water vapor as a refrigerant, where suitable compressors are already available. These systems are mechanical vapor recompression systems. Furthermore, steam generation with heat pumps is an important development, as these heat pumps can be integrated easily in existing equipment and steam networks. (IEA, 2022).

In this contribution, a simulation analysis of heat pump integration into an amine-based carbon capture process is presented. In particular, we investigate the application of carbon capture in steel processing: currently reheating furnaces are operated on natural gas with corresponding CO_2 emissions. Switching to hydrogen may not be possible due to detrimental influence on steel quality or lack of experience and availability of hydrogen burners for such complex high-capacity furnaces. Thus, we developed a concept where CO_2 is captured from the flue gas with an amine scrubber. It is methanized with green hydrogen to produce synthetic natural gas which can be combusted in the furnace again. Details on this concept are published by Leibetseder et al (2023). In this contribution, we add a heat pump to the amine scrubber of the system, to improve energy efficiency and thus reduce operating costs. Therefore, available heat sinks and heat sources in the process are evaluated. Both internal and external options are considered, such as recovery of latent energy from the desorber exhaust gas, internal heat transfer, steam supply for the desorber, or providing heat for district heating or other industrial processes. The analysis is based on a stationary simulation model of the furnace and the industrial scale carbon capture system in IPSEpro, which is used to study different scenarios, such as varying carbon capture rates and different sorbents. Heat pumps that are market-available or close to market introduction are included in the analysis. The solutions are compared and presented in the form of Sankey diagrams. They are evaluated in terms of energy savings, investment and operation costs and process complexity.

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CONFERENCE TOPIC

Solutions for Energy Efficiency, Approaches towards net-zero/negative emissions in the industry including CCU

USE OF WASTE HEAT POTENTIALS AND FLEXIBILITY ELEMENTS TO SPEED UP DECARBONIZATION IN AUSTRIAN THERMAL SPAS

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SUMMARY

Austria's 38 thermal baths offers a unique opportunity to harness deep hydrothermal geothermal energy, reducing their reliance on fossil fuels and decreasing CO2 emissions by over 50,000 tonnes annually. The GEOMAT project's core focus is on efficiency enhancement by integrating various heat pump technologies, optimizing energy management, and transitioning to renewable energy sources for complete decarbonization. Geothermal energy is pivotal for Austria's sustainable energy future, with a particular emphasis on making it economically appealing for significant energy consumers, including thermal spas, municipalities, energy providers, and industries. By leveraging innovative heat pump systems and intelligent control concepts, GEOMAT aims to maximize energy efficiency and create flexibility in electricity and heating networks, thereby fostering synergy and systemic benefits.
Keywords: geothermal heat, thermal spas, heat pump, district heating, energy management, flexibility

INTRODUCTION

Austria, renowned for its 38 thermal baths, is a top European tourist destination with immense potential for harnessing deep hydrothermal geothermal energy from depths exceeding 400 meters within water-bearing strata [1]. These thermal baths are significant energy consumers, with the potential to cut carbon emissions by up to 50,000 tons of CO2 annually. To preserve these facilities and make them more environmentally friendly, the focus should be on increasing the use of geothermal heat for their energy needs [2]. This involves optimizing existing infrastructure and exploring innovative solutions. Many thermal spas in Austria currently rely on fossil fuels for their substantial energy demands. For example, Sonnentherme Lutzmannsburg consumes 16 GWh of heat from natural gas each year, while Reduce Therme Bad Tatzmannsdorf relies on 9 GWh of heat from natural gas, and H2O Hoteltherme utilizes 5 GWh of heat sourced from biomass. Therefore, these thermal bath facilities hold substantial potential to play a crucial role in decarbonization and energy efficiency efforts by 2030/2050.

FRAMEWORK CONDITIONS AND METHODOLOGY

Thermal bath facilities in Austria are unique energy systems with distinct characteristics, including [3, 4, 5, 6, 7]:

- Untapped waste heat potential from sources like splashing water.
- Opportunities for energy savings through reduced pool heat losses.
- Potential for energy savings through temperature-optimized supply systems, including infrastructure upgrades like heat exchangers.
- Large storage capacity in pool water content, often overlooked in control strategies.
- Complex control challenges due to simultaneous heating and cooling demands, often managed using simplistic methods.
- Utilization of thermal capacities for peak shaving and load shifting, tied to visitor patterns and weather forecasts, but often lacking advanced data-driven forecasting.
- Potential for effective energy management systems to integrate supply and demand-side factors.

Therefore, the GEO.MAT project aims to create carbon-neutral thermal baths by optimizing geothermal energy utilization. This includes repurposing unused splashing water at 30°C, reducing pool heat losses, and implementing temperature-oriented heating supply. The project also explores integrating non-stationary splashing water utilization and other renewable resources like biomass and solar power. An appropriate energy management system (EMS) is vital for this complex system.

The shift to a carbon-neutral energy supply therefore involves several measures:

- Using geothermal splashing water (waste heat at 30°C) through AHP and/or CHP to reduce the external heat demand (gas or biomass)
- Implementing demand-side management with data predictive control (DPC) for peak shaving and load shifting.
- Applying model predictive control (MPC) for the supply side, considering generated forecasts.
- Integrating all measures for optimal operation and load, including sector coupling options based on the facilities' high thermal inertia.
- Replacing gas with biomass and incorporating flue gas condensation through AHP

DEMONSTRATION CASES AND RESULTS

Innovative energy system concepts including different measures for utilizing geothermal waste heat and increasing renewables' integration in thermal baths will be demonstrated in two Austrian facilities:

- Demo project 1: Sonnentherme Lutzmannsburg, which consumes 1.67 million m³ of natural gas annually and emits over 4,200 tons of CO_2 for heating.
- Demo project 2: H2O Hoteltherme, which currently uses biomass for their 5,000 MWh/year heat demand.

In both demonstrations, the focus is on efficiently utilizing geothermal waste heat, optimizing control systems, and reducing carbon emissions, contributing to more sustainable and environmentally friendly thermal bath operations in Austria. Initial analyses and results in the demo projects confirm the substantial waste heat potential.

Due to hygienic reasons for water treatments in the considered spa facility (DEMO 1 – Sonnentherme Lutzmannsburg), 54 till 71 m³ wastewater with about 32°C is daily produced and stored in a wastewater basin (WWB) for several hours, bevor it is discharged into the sewer. On the other hand, there is a high demand for heating energy for pool heating in spa areas at low temperature from about 45°C. So, the high potential of energy in the WWB can be utilized to partly cover the heat demand of pools using heat pump technology.
Figure 1 shows an example of the determined waste heat utilisation potential for a day in early April. It was analysed how much heat is contained in the wastewater and how it can cover the heat losses of one of the existing outdoor swimming pools. It is estimated that the wastewater can be used till 10°C, taking temperature difference of intermediate heat exchangers into account. So, energy of approximately 2 MWh per day can be utilized and cover 2/3 of the energy demand of the outdoor pool (SP).
In the bottom right-hand diagram, the temporal trend of the heating capacity for the SP is shown in orange. Since the pool temperature is lowered during the night hours (to reduce heat losses), there is a peak in heating capacity in the morning hours. It is evident that the heat from the WWB, which is represented by the green area, would be completely consumed during this reheating process. Backup heat sources are necessary to cover the further need which is illustrated as red area.
Additionally, in the top right-hand diagram, the cumulative temporal trend of heat quantities is depicted. From approximately 02:00 AM, the wastewater is available as a heat source, with a total of about 2 MWh. This is used for pool heating until no more heat can be extracted from the wastewater (green curve). From this point onwards, other heat sources must be utilized (red curve). In comparison, the cumulative heat demand of the outdoor pool is shown in orange. It is evident that by fully utilizing the heat content of the wastewater, the heat consumption of backup sources, in this case a gas boiler, can be reduced by approximately 68%. This share decreases during winter months, but in the summer months, the energy need for the SP can be completely covered.

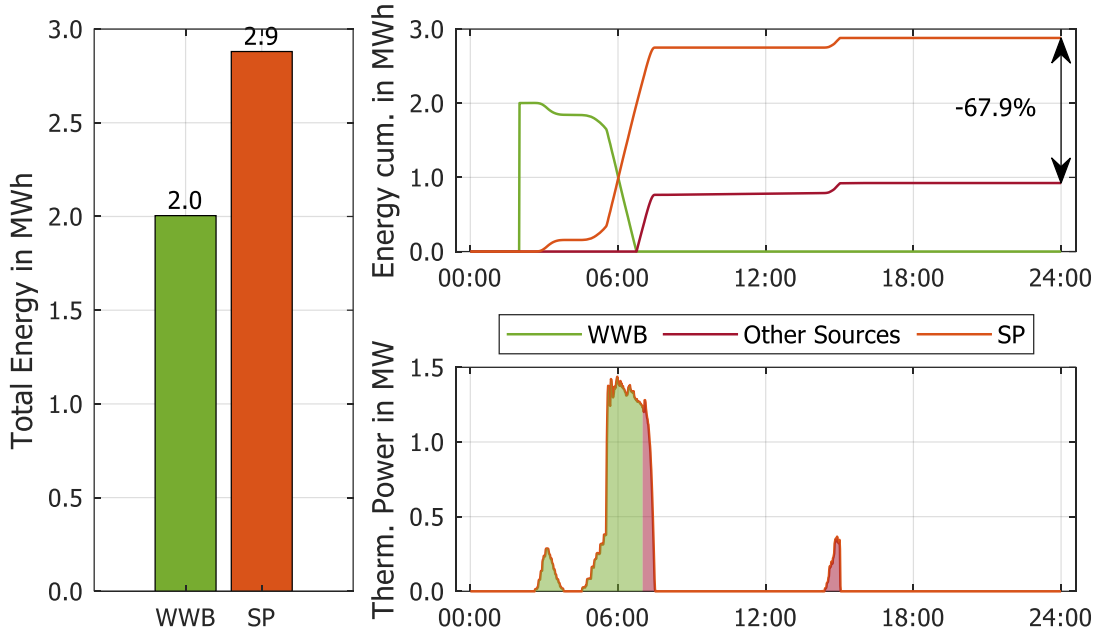

Fig. 1: Waste water utilization potential for heating demand of an outdoor swimming pool

Actually, the peak loads can hardly be covered by a heat pump if an efficient operation mode is expected. Therefore, peak shaving and load shift methods are under investigation to, which should be realised using data driven predictive control strategy.

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CONFERENCE TOPIC

Main related Conference Topics of the abstract

- Excess Heat Energy and Resource Recovery from Low-grade Sources
- Solutions for Energy Efficiency

HEATING AND COOLING WITH RENEWABLE ENERGY FROM WASTEWATER – A LARGE SCALE CASE STUDY IN VIENNA

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SUMMARY

Energy from wastewater is recognized as a renewable energy source and can add a valuable contribution to the EU's path to decarbonization. With modern heat exchangers and heat pumps, buildings and districts can be supplied with energy for heating, cooling and water heating. Based on the successful results of the implementation in Vienna Blumental, another project in Vienna has been rolled-out: The Vio Plaza building complex will be supplied with energy from wastewater for heating (1.2 MW) and cooling (6 MW). This article will present the case study at Vio Plaza, give a detail description of the system design and (by the time of the conference) will deliver first-hand information about operation of the installed system (launch November 2023). Special focus will be put on the innovative monitoring system and resulting monitoring data. Based on these results, further knowledge about these systems will be gained to support the increasing implementation of this technology.
Key words: Energy from wastewater, decarbonization, building sector, heating and cooling, monitoring.

INTRODUCTION

Since 2018, the EU recognizes energy from wastewater as a renewable energy source and thereby its valuable contribution to the achievement of the climate goals (Directive (EU) 2018/2001). Space and water heating require ~ 75 % of the energy consumption, which today is mostly covered by non-renewables (REN21, 2023). Energy from wastewater is available all year round and can be tapped with modern heat exchangers and heat pumps. Still, wastewater in Austria is relatively unused in this regard and thus offers great potential for decarbonizing heating and cooling.

The research project ThermaFLEX has proven that the technology for heat recovery from wastewater is ready for up-scaling. Within the project, a demonstration has been implemented at the headquarters of "Wien Kanal" in Vienna Blumental. For the project, an innovative system combination of in-sewer heat exchangers, heat pumps and monitoring has been installed in 2021 to cover the building's heating and cooling demand. One of the main findings of this project is the importance of smart monitoring to ensure smooth operation, survey the influence of the system on the sewage and increase the overall efficiency (Kelz et al., 2023; Wiedemann et al., 2021).

These important results have been directly transferred and rolled out to a new project currently under construction: The Vio Plaza Center in Vienna. Energy from wastewater will be one of the main sources for renewable heating and exclusive source for cooling for a whole building complex with mixed use on an area of 22 000 m². The system is already successfully constructed and will start operation in November 2023. First learnings and results are presented in this abstract and will be updated until the conference in 2024.

CASE STUDY VIO PLAZA

Vio Plaza is a building complex combining uses such as office spaces, retail and living (~3500 people) in Vienna, Austria. Central part of the project is the use of wastewater energy for heating and cooling. The operation of the system will be done by "Wien Energie" as a contractor. Due to the high wastewater energy potential at the project site, the complete cooling requirement of up to 6 MW power can be covered by system. On the heat side, the base load of 1.2 MW power is supplied from the sewer, the peak load in winter is covered by district heating.

This means that this system can be operated very economically, which significantly reduces the future operation costs of the building compared to conventional fossil fuels. It is currently the largest facility of its kind in Austria.

SYSTEM DESCRIPTION

The planning and construction of the energy from wastewater system was conducted by Rabmer GreenTech GmbH in cooperation with the company Uhrig. The trenchless construction through assembly manholes was finished within two months. The main sewer is split into two lines to facilitate operation and maintenance, as well as to increase yields. Each sewer (1000 x 2250mm) is equipped with 185 m of Therm-Liner heat exchangers. For subsequent temperature adjustment for heating and cooling, “Wien Energie” will operate the heat pumps.
Based on the results of the ThermaFLEX project, the same innovative monitoring system was installed to survey the energy production and the impact on sewer operation. The system provides information on the conditions in the sewer (wastewater temperature before and after heat exchangers, wastewater level, flow, pressure, etc.) as well as on energy production. The monitoring system is directly connected to the control system of the energy center and is crucial for controlling heating and cooling of the Vio Plaza Center.

Fig. 23: Vio Plaza (left), installation of heat exchangers (middle) and supply and return line (right) (Source: Wiedemann/Rabmer GreenTech GmbH).

EXPECTED OUTCOMES

In the full paper, special focus will be put on the detailed description of the system and monitoring, as well as further learnings from the project implementation. Heating and cooling of Vio Plaza Center based on wastewater is currently the largest facility of its kind in Austria und will therefore have a lighthouse function for the region. The findings from this large-scale project are important for the roll-out of future projects in municipal and industrial sewers and can be used to gain important information for energy spatial planning.
The article aims at validating this technology for the use of energy from wastewater for bigger building complexes and foster the acceptance of this (in Austria and Europe) still often critically viewed renewable energy source.

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CONFERENCE TOPIC

Excess Heat Energy and Resource Recovery from Low-grade Sources

DECARBONISATION OF DRYING AND COOKING PROCESSES: INDUSTRIAL CASES

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SUMMARY

Companies are committed to reducing their environmental impact, driven by international conventions on climate change. In France, the national strategy aims t**o reduce industrial greenhouse gas (GHG) emissions by 81% by 2050**. Among the energy-intensive industrial processes, drying and cooking represent a major challenge for industrial decarbonisation and are often combined. Therefore, our study focuses on the **decarbonisation of drying and cooking processes** in applied industrial case studies up to 2050, in line with the industrial challenges and **developed in collaboration with industrial players** (CTMNC, Malteurop and CETIM). Each of these cases examines **energy efficiency, waste heat recovery, electrification** and **decarbonised energy solutions** (including **solar thermal, district heating, hydrogen, biomass**). Applications include **roof tile drying, powder paint line drying** and **barley malt kilning.** Energy efficiency achieves GHG reductions, and switching to electricity or low-carbon energy can further **reduce emissions by 78%-96%, often reducing installation costs**.

ABSTRACT - OBJECTIVES AND METHODOLOGY

Our study focuses on the decarbonisation of drying and cooking processes to determine the best option for industrial application cases, aiming to represent the diversity of processes in the industry with different sectors, temperatures and power requirements. These industrial case studies have been designed with the help of industrial actors dedicated to the sector:

- Roof tile drying (90°C – 1,5MW) and cooking (1000°C – 6MW), a plant submitted to the EU-ETS and designed in collaboration with the CTMNC, the French competence centre for natural building materials.
- Powder paint line drying (120°C – 245kW) and cooking (220°C – 450kW), designed in collaboration with the CETIM, French competence centre of mechanical industries.
- Barley malt kilning (60/85°C – 1/2,5MW), designed in collaboration with Malteurop, industrial malt producer.

Each of these cases examines energy efficiency, excess heat recovery, electrification and decarbonised energy solutions (including solar thermal, district heating, hydrogen, biomass.

The aim of the study is to examine the application of these different decarbonisation solutions in the application cases and to compare the results up to 2050 from an energy, economic and environmental perspective). The economic and carbon impacts are based on EnerData's electricity and gas projections, supplemented by our expertise from previous studies (ADEME, ALLICE, Blunomy, CETIAT). EnerData is a company specialising in the analysis and modelling of global energy issues. It produces data forecasting models taking into account political, economic and environmental aspects. Three scenarios were developed and used in the study, corresponding to different levels of environmental commitment, reflected in targets for limiting the increase in global average temperature by 2050:

- Grey: Rise above 3°C

Very little effort is made to combat global warming, with fossil fuels continue to be used, little effort is made to improve energy efficiency and energy consumption continues to rise.

- Blue: Rise between 2°C and 2.5°C

Stronger environmental commitments, in line with current policies and work on energy needs, particularly in OECD countries (Organisation for Economic Co-operation and Development).

- Green: Stay below 2°C

Reflects a strong commitment to the environment, in line with the Paris Agreement, and even more so, a strong focus on energy efficiency and renewables.

ABSTRACT – RESULTS

The results are summarised for each case in Figures 1, 2 and 3. In all cases, a significant net reduction in GHG emissions can be achieved by applying energy efficiency solutions – more than 30%. Electrification and renewable energy make it possible to go even further, achieving between 78% and 96% reductions in GHG emissions.

These reductions in GHG emissions are most often associated with a reduction in the total cost of the installation, in particular by reducing the operating costs associated with energy consumption. Only case 1 (tiles) differs from the other cases, mainly due to the lower cost of gas (due to the EU ETS quotas), which makes renewable solutions less competitive.

Apart from the economic aspect, there are two main ways to differentiate one renewable energy source from another for a given process:

- The technical feasibility of the solution, including the availability of renewable energy for a given site.
- The temperature levels involved have a major impact on the efficiency of the systems and therefore on the amount of GHG emitted per unit of heat used.

To help compare the different solutions, an estimate of the GHG emission factors as a function of the influencing temperature levels is shown below in the Figure 4 below (the assumptions used to produce this graph are detailed in the report).

FIGURES

Modelling
SI = Initial Situation
SoEE = Energy Efficiency Solution
SoGO = Solution using the Guarantee of Origin
SoElec = Electrification Solution
SoH2 = Hydrogen Solution
SoBois = Biomass Solution
SoSol = Solar thermal Solution

Cost and CO2e emission scenarios
Grey: very low environmental commitment, in some cases below the commitments made by France (climate impact > 3°C)
Blue: commitment in line with current policies currently in place (impact between 2 and 2,5°C)
Green: strong commitment, sometimes going beyond existing commitments (impact < 2°C)

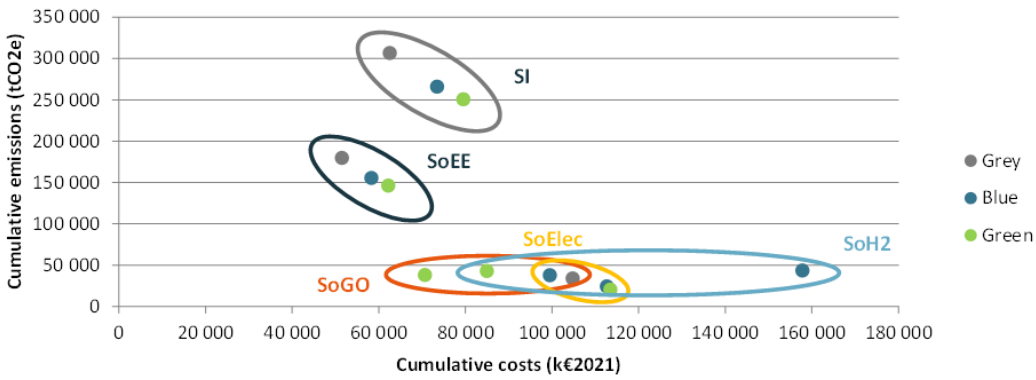

Figure 1 - Comparison of the cumulative emissions and costs of the different solutions in the "roof tiles" case

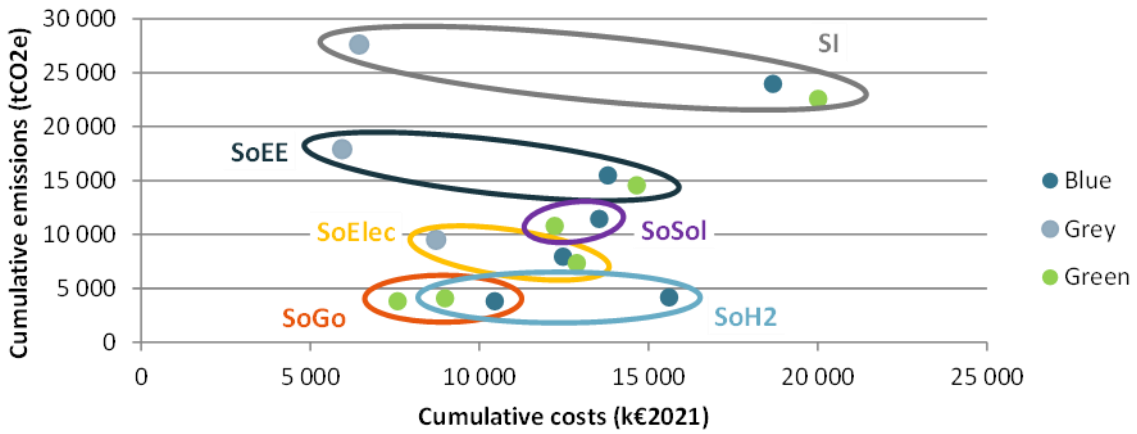

Figure 2 - Comparison of the cumulative emissions and costs of the different solutions for the "paint line" case study

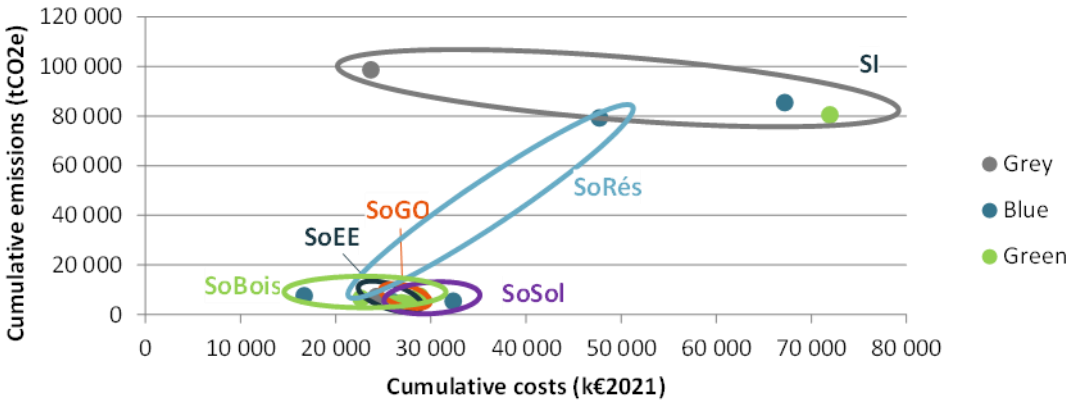

Figure 3 - Comparison of the cumulative emissions and costs of the different solutions in the "Malt kilning" case study

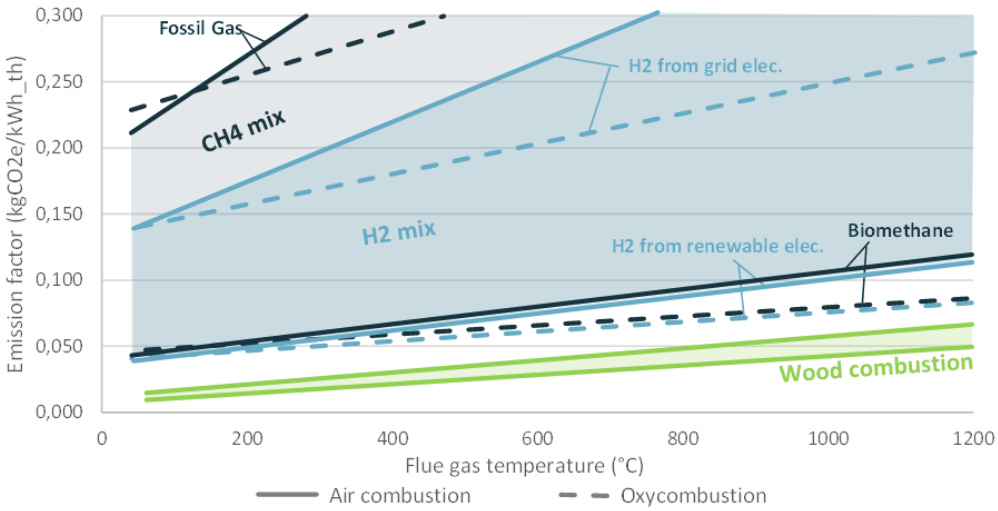

Figure 4 - Typical GHG emission factors for thermal energy generated by different fuels (source CETIAT)

CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Solutions for Energy Efficiency
- New technologies for realizing energy and resource efficiency (Process Intensification)

EDDY – ENHANCED DRYING: FROM DRYING KINETIC EXPERIMENTS TO A DIGITAL TWIN OF THE DRYING PROCESS

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SUMMARY

EDDY - Enhanced Drying focuses on the advancement of industrial drying processes in collaboration with two industrial partners engaged in drying of food products. The initiative employs three approaches to enhance the existing drying procedures, namely an experimental study of drying kinetics, inline product moisture measurements, and process optimization with the help of a digital twin. This work shows the path from the experimental study of drying kinetics and its use to a digital twin of the industrial drying process. The drying kinetic is evaluated using a recently constructed continuous gravimetry drying apparatus, utilizing a methodology of the characteristic drying curve (CDC). The drying curve serves as a basis for the mathematical description of the industrial drying process. The model of the drying process is used to anticipate the effects of various environmental and process parameters on the final product. A key role plays the inline measurement of the product moisture with newly developed near infrared (NIR) sensors to feed the digital twin with real world process data. The primary goal is to ensure product quality under varying operating conditions e.g., weather conditions and enable energy and economic savings.

Keywords: EDDY – Enhanced Drying, CDC – characteristic drying curve, drying kinetics, continuous gravimetry, digital twin, near-infrared sensor

INTRODUCTION

Industrial drying is a well-known process that is used worldwide for various purposes as for example weight reduction or preservation. Nevertheless, about 85% of all dryers are fossil-fired, convective exhaust air dryers, of which about 99% release the moist air to the atmosphere without using it further. Studies show that drying processes account for 12-25% of total industrial energy demand worldwide (Mujumdar et al. 2006). The most relevant industries are paper, sugar, paints, textiles, bricks, and food. Experimental investigations on lab-scale and modelling of the drying process have a huge potential to increase energy efficiency. The drying process model can help either by evaluating heat recovery potentials or by optimizing process parameters, e.g., to predict the influence of environmental changes to maintain product quality, minimize down-time, and avoid product rejects. In this work we analyse the industrial drying process of bread dumpling cubes.

METHOD

In this work the full workflow combining the state-of-the-art as well as new modelling and new measurement approaches are applied. To model a drying process, the following topics, depending on the model purpose in various detail, must be addressed (Mujumdar et al. 2006):

- **Balance equations** for mass (product and drying agent), energy and species (water). For closing the balance equations, custom inline MOEMS-based NIR-sensors**Fehler! Verweisquelle konnte nicht gefunden werden.**, are developed and deployed in the drying process to deliver real-time moisture data.

- **Constitutive equations** to connect fluxes in the system to respective driving forces and drying kinetics. Drying kinetic is evaluated using a prototype drying chamber, see Figure 0-2, designed for single particle drying. The chamber can maintain a constant air velocity, temperature and humidity profile of the air which is required to evaluate the CDC (Rezucha 2023).
- **Equilibrium relationships**. A sorption isotherm model (GAB) is obtained by lab experiments for breadcrumbs and bread dumpling cubes.
- **Property equations**.
- **Geometric relationships** to convert flowrates present in balance equations to fluxes present in constitutive equations.

To bridge the similarity gap between lab scale measurements, account for model errors, and changing process environments, an optimized model is periodically calibrated to real world process data. In this twinning cycle state-of-the-art methods for parameter identification and fitting are applied. Based on the predictions made by the digital twin optimal process parameters are suggested**Fehler! Verweisquelle konnte nicht gefunden werden.**.

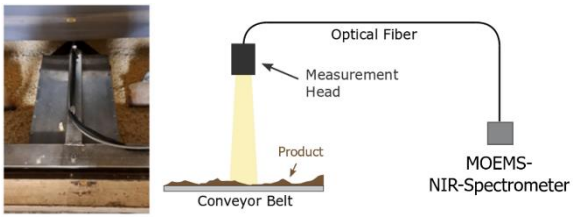

Figure 0-1: NIR-based product moisture sensor.

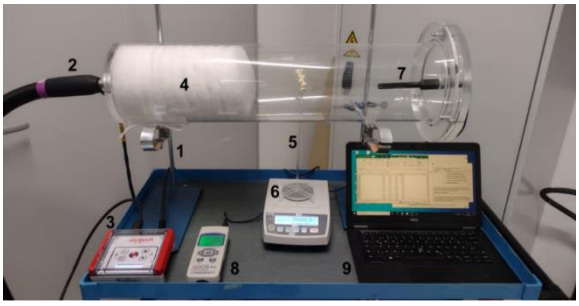

Figure 0-2: Drying kinetics test bench.

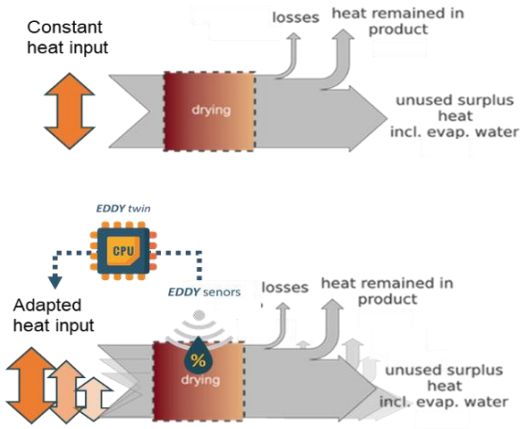

Figure 0-3: Digital twin with process data of product moisture.

RESULTS

A complete workflow from lab experiment to a digital twin of food-stock drying process is presented. It utilizes a custom-made test bench for determining the characteristic drying curve of breadcrumbs and dumpling cubes as well as a newly developed MOEMS-based NIR moisture sensor for inline measurements.

CONCLUSION

Industrial drying emerges as an attractive candidate for enhancing the process energy efficiency, achieving higher energy savings and, subsequently, decarbonization of the process. The presented workflow enables the creation of suitable models for the deployment in other drying processes such as paper, sugar, paints, textiles, bricks and more, to assist the process engineers in achieving maximum energy efficiency.

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CONFERENCE TOPIC

Solutions for Energy Efficiency, Digitalization for Future Energy Systems

3-LEVERS OF EMISSION COTROL-MODELING FRAMEWORK: MODELING GHG EMISSIONS WHEN DIRECT MEASUREMENT IS NOT POSSIBLE

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SUMMARY

Accurate measurement and reporting of greenhouse gas (GHG) emissions are imperative for production companies. The most accurate measurement would be to directly measure the GHG emissions for the finished goods. However, in many companies, this is not possible due to the unavailability of adequate measurement sensorics. In this situation, the GHG emission has to be modeled using a suitable activity data-based measurement metric. In this paper the 3 Levers of Emission Control (3-LoEC)-modeling framework is used to specify such metrics. In the simplest case, the three coefficients of the 3-LoEC framework, i.e. production, power, and emission coefficients, are multiplied. But in more realistic cases, the measurement model has to consider parameters that are fluctuating over the production activities. In this paper, the problem of selecting adequate measurement metrics for the simple and the realistic use case are addressed. The application of the 3-LoEC-modeling framework is demonstrated via a 'popcorn making' activity and an 'injection molding' activity.

Conference Topics: Life Cycle Assessment.

ABSTRACT

Greenhouse gas (GHG) emissions have become a pivotal concern for production companies in the current industrial landscapes. In this context, the GHG Protocol Product Life Cycle Accounting and Reporting Standard (GHG-Protocol, 2011) serves as a guiding instrument to account for such emissions: "*The Product Standard accounts for the GHG emissions and removals that occur during a product's life cycle*" (GHG-Protocol, 2011, p. 7). For production companies, understanding and managing GHG emissions is of paramount importance. This necessitates a meticulous consideration of product GHG inventory requirements, as outlined in the GHG Protocol (GHG-Protocol, 2011). This standard underscores the importance of identifying data types needed for GHG measurement, distinguishing between "direct measurement" and "activity data-based" modeling approaches. "*Identifying data types – Identifying the data types used in an inventory will provide companies with a better understanding of the data and their quality. Typically, data can be gathered in one of two ways: 1. Directly measuring or modeling the emissions released from a process. 2. Collecting activity data and emission factors for a process and multiplying the activity data by the emission factor*." (GHG-Protocol, 2011, p. 51).

Ideally, the most accurate approach would involve "direct measurement" of GHG emissions associated with finished goods. However, in real use cases, many companies face a challenge due to the unavailability of adequate measurement sensorics. Consequently, production companies often resort to employing "activity data-based" modeling approach to measure their GHG emissions. Such approaches involve collecting detailed activity data and emission factors within the production activities, followed by the multiplication of activity data by the corresponding emission factor. However, while activity data-based modeling offers an alternative to direct measurement, it requires meticulous data collection and suitable activity data-based measurement metrics. The effectiveness of this approach is based on the reliability and accuracy of the data gathered and the selected metrics. Therefore, the construction of suitable measurement metrics becomes crucial, requiring a careful examination of the various parameters influencing emissions during production activities.

This paper addresses the specification problem of the activity data-based GHG measurement metrics within the 3 Levers of Emission Control (3-LoEC)-modeling framework (Baumüller and Schwaiger, 2023). The 3-LoEC-framework aligns the reporting requirements from the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standard (ESRS) E1 with the activity data available in Time Driven (TD)-ABC (Kaplan and Anderson, 2007) as well as Resource Consumption Driven (RCD)-ABC accounting systems.

The flexibility of the 3-LoEC-modeling framework allows the development of different GHG emission measurement metrics for covering a wide range of use cases. In the simplest case the power coefficient of the 3-LoEC-metric is constant over the activity's production time, i.e. the production coefficient. In this case the activity's energy consumption is just the mathematical product of the production and the power coefficient. Multiplying the activity's energy consumption with the emission coefficient gives the activity's GHG emission in form of the primary unit carbon footprint (*upCFP*). In the more realistic use case the power coefficient is fluctuating over the activity's production time, so that the mathematical product of the production and the power coefficient would not correctly specify the activity's energy consumption. In this case the mathematical product has to be replaced by an integral calculation where the fluctuated power coefficient is integrated over the activity's production time. Furthermore, if the activities' resulting energy consumptions are not exactly fitting actual energy consumptions the calculated consumptions have to be scaled to fit to the actual values.

The provided solution of the paper's underlying specification problem is consistent with the Design Science Research (DSR) methodology (Peffers et al., 2007). The specification problem actually is a design problem related to the specification of the adequate 3-LoEC-metric from the 3-LoEC-modeling framework. For identifying such a metric, the criteria of a correct measurement of the activity's energy consumption and its related emission factor has to be fulfilled. By comparing the activity data-based values with the actual values the validity of the 3-LoEC-metrics will be demonstrated for two uses cases. For the simple use case a 'popcorn making activity' and for the more realistic case a 'injection molding activity' for producing a 'food-bowl' are used.

The structure of this paper is as follows: Following the introduction, the GHG Protocol product life cycle will be investigated with a special focus upon the GHG emission measurement requirement for production activities at the company level. Next, the 3-LoEC modeling framework is presented, where the three pivotal coefficients, i.e. production, power, and emission coefficients are highlighted, and the relationship to the TD-ABC activity data is explored. Building upon this understanding, the adequate 3-LoEC-metric for the simple as well as the more realistic uses case will be derived. Finally, the paper is summarized and concluded with an outlook concerning the inclusion of further GHG emission components in form of the products secondary carbon footprint (*usCFP*) and the Emission (*E*)-liability (Ramanna and Kaplan, 2021) with respect to finished good's consumed materials and used equipment resources.

DESIGN AND COMPARATIVE ANALYSIS OF A RENEWABLE ENERGY BASED RURAL DISTRICT HEATING SYSTEM

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SUMMARY

This research focuses on adapting renewable energy sources for high temperature rural district heating systems. By utilizing Polysun® software [Vela Solaris AG, (2023)], simulations explore combinations of Wood Chips Fired (Biomass), Air-Water Heat Pumps, Geothermal Heat Pumps, Solar Thermal, and Photovoltaic technologies. Emphasizing carbon neutrality, the study considers space heating and domestic hot water production. Data acquisition in Middle Franconia was carried out using relevant data Hotmaps [Hotmaps, (2023)], considering number of houses, construction year, and net heated area. The study concludes with optimized models, empowering communities to make informed, investment effective decisions for sustainable heating solutions. This research contributes significantly to rural heating advancements, promoting energy efficiency and environmental sustainability.

INTRODUCTION

Rural district heating is highly adaptable, offering flexibility in utilizing diverse energy sources and transitioning between them. Unlike the complex process of replacing numerous small boilers in individual buildings, modifications or exchanges can be efficiently done in one central unit [Jan Erik Nielsen, Per Alex Sørensen, (2016)], This enables swift changes in the rural heating sector when favorable economic and political conditions align. Another reason is that rural district heating is very comfortable for the customer and needs only a minimum of maintenance and involvement from the user side.

This research addresses the complex challenges faced by rural heating communities, including carbon dioxide reduction goals, an aging population, volatile fuel prices (oil and gas), government restrictions, affordability concerns, self-sufficiency and the need for energy independence. Presently, rural district heating systems rely on technologies such as biomass-fired systems, Combined Heat and Power (CHP), and decentralized approaches involving oil, gas, and wood.

METHODOLOGY

Motivated by the goal of achieving carbon neutrality by 2045, reducing dependency on fluctuating markets during pandemics and wars, increasing the utilization of renewable resources, and providing affordable heating solutions, this project employs a comprehensive methodology. The study begins with a baseline design incorporating a Wood Chips Fired (Biomass) system with a boiler. Biomass is in abundance in rural communities, but it has market dependency. Subsequent simulations explore advanced and sustainable technologies, including combinations of Wood Fired,Air-Water Heat Pumps, Geothermal Heat Pumps, Solar Thermal, and Photovoltaic. Through these simulations, the research aims to identify approaches with the least carbon dioxide emissions and the highest investment efficiency, ultimately providing optimized options. This includes a specific focus on space heating and domestic hot water requirements, allowing communities to select heating solutions aligned with their budget constraints or carbon emission targets.

Data acquisition for a selected area, specifically the Middle Franconia region, is done using Hotmaps[Hotmaps, (2023)]. This process can also be replicated for other regions. Factors considered include the number of houses,

year of construction, net heated area, and the exclusion of new renovation, focusing on existing building conditions. District heating is the efficient way to supply (existing/historical) buildings with large fractions of renewable heating(renovation to zero-energy houses is not possible here) [Jan Erik Nielsen, Per Alex Sørensen, (2016)], utilizing Polysun® software which is a simulation tool for researchers and engineers to design and optimize renewable energy systems with precision [Vela Solaris AG, (2023)]. The research involves designing the approach, conducting hydraulic simulations, and determining the dimensioning of heat generation devices.

The study's conclusion presents a set of base parameters and models, empowering rural communities to make informed decisions among a range of heating models. This facilitates the selection of approaches based on feasibility, resource-saving potential, and energy optimization, specifically for space heating and domestic hot water production. The outcomes of this research significantly contribute to the advancement of sustainable heating systems, providing a guide for the implementation of rural heating systems. Ultimately, this work promotes energy efficiency and environmental sustainability in rural and similar community settings.

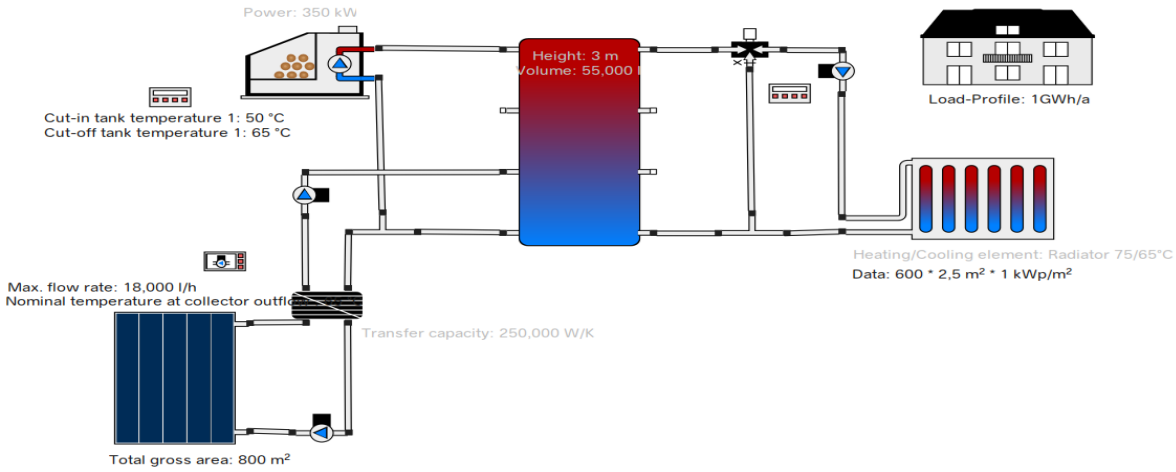

Fig.1: System diagram designed for Biomass + Solar thermal

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CONFERENCE TOPIC

Future District Heating and Cooling Technologies
Solutions for Energy Efficiency

MAXIMIZING ENERGY STORAGE DENSITY AND STABILITY OF SALT IN POROUS MATRIX COMPOSITES

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SUMMARY

Salt in porous matrix composites can be tuned for thermal energy storage applications. This study presents a new method of calculating optimal volumetric salt-to-matrix ratios for sorption cycles to maximize energy storage density for specific operating conditions, by considering the matrix pore volume, the sorption equilibrium curve, and the solution density curve. The vapor sorption "flooding thresholds" are calculated for $CaCl_2$, LiCl and LiBr in meso- and macroporous silica gel matrices. The energy storage density for $CaCl_2$ confined in silica gel with a pore volume of 1.54 cm^3/g can reach 2.9 GJ/m^3 for a typical thermal energy storage cycle.

INTRODUCTION

Salt in porous matrix composites – such as mesoporous silica gels impregnated by hygroscopic salts ($CaCl_2$, LiBr, LiCl, etc.) – have sorption thermal energy storage and heat transformation applications [1]. To achieve high energy storage density (1.0-3.0 GJ/m^3, at material level), salt-to-porous-matrix ratio should be maximized. However, overloading the matrix with salt is counterproductive since during vapor sorption cycles the salt solution can flood the matrix, resulting in reduced dynamics, leakage (migration and loss of salt), and corrosion of metallic system components. When added to mesoporous silica gelt, salt preferentially fills small pores, decreasing open pore volume and surface area, while increasing average pore size measured by nitrogen porosimetry [2]. In this study, the composite flooding threshold for different combinations of matrices (porous silica gels with pore volumes 0.8-1.54 cm^3/g) and hygroscopic salts ($CaCl_2$, LiCl, and LiBr) is determined from the sorption equilibrium and the salt solution density [3] by comparing available matrix pore volume and volume of the solution for specific operating conditions (temperature, T, and relative pressure, P/P_0). Energy storage density is then calculated based on the flooding threshold for different thermal energy storage cycles.

METHODS

Concentrated aqueous salt solutions were prepared from oven dried (150 °C, 4 h) hygroscopic salts ($CaCl_2$, LiCl, and LiBr; Sigma Aldritch). Silica gels (mean pore diameter, d_{pore} = 17, 31, and 45 nm, Table 1) were dried at 150 °C for 4 hours and combined with the aqueous solutions to prepare composites with 20, 30, 40, and 50 wt.% salt in ~10 g batches. The concentration and volume of salt solution used for each batch was tuned to the moisture capacity of the silica gel ($V_{solution}$= 2 × V_{pore}) creating a slurry, which was oven dried at overnight at temperature steps from 80 °C to 120 °C. Samples were studied by using thermogravimetric vapor analyzer to establish sorption equilibrium between composite and water vapor, and sorption/desorption hysteresis, nitrogen porosimetry for composite's surface characterization, and repeated sorption/desorption cycling (RH 10-80% at 55°C) of the samples in an environmental chamber to observe composite's leaking.

Table 1: Mesoporous silica gels sourced from SiliCycle Inc. characteristics determined by nitrogen porosimetry.

Name	Grain	d_{pore}, nm	S_{BET}, m^2/g	V_{pore}, cm^3/g
SiliaFlash, 150 Å, 0.2-0.5 mm (B150)	Irregular grain	16.7	290.5	1.05
SiliaFlash, 300 Å, 0.2-0.5 mm (B300)	Irregular grain	30.9	177.7	1.54
SiliaSphere PC, 500 Å, 0.2-0.5 mm (B500)	Spherical grain	45.1	63.4	0.85

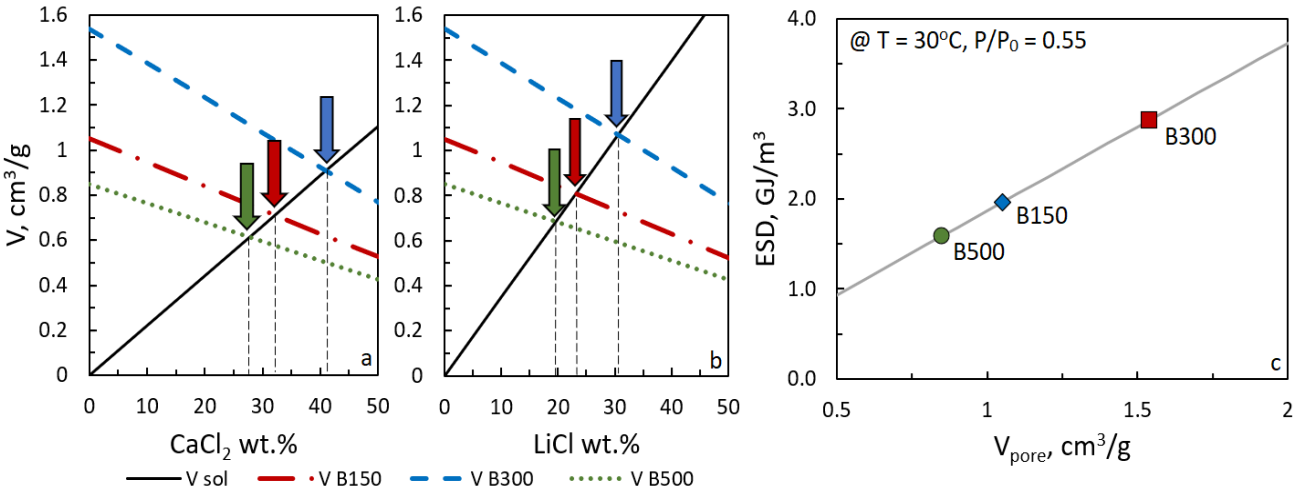

Fig. 1. Specific pore volume of three silica gel matrices (dashed/dotted lines) and specific volume of salt solution (solid line) for $CaCl_2$ (a) and LiCl (b) composites; and volumetric energy storage density vs. dry matrix pore volume for composites with $CaCl_2$ (c) at typical sorption conditions for thermal energy storage cycle: T = 30°C and P/P_0 = 0.55. Downward arrows are composite flooding thresholds. Energy storage density calculations are based on dry silica gel density.

DISCUSSION AND RESULTS

For selected thermal energy storage sorption conditions (P/P_0 = 0.55), the salt solution will flood the sorbent if the composite $CaCl_2$ to silica gel (B150) weight ratio exceeds 1:2 (Fig. 1a). Therefore, for stability, the selected salt and matrix, the salt must be less than 32.2 wt.% to prevent salt solution leakage and corrosion. Silica gel B300 has 50% greater pore volume allowing stable composites with greater salt loading (41 wt.%). Calculated energy storage density is 2.9 and 2.0 GJ/m^3 for B300 and B150 composites under operating cycle condition 20/30/90 °C, respectively (Fig. 1c). The aqueous LiCl solution that forms under the same conditions (P/P_0 = 0.55) has a lower density (1.15 g/cm^3 vs 1.33 g/cm^3 for $CaCl_2$ aqueous solution) due to the difference in molecular weight (42.4 g/mol vs 111 g/mol) and sorption uptake (7 mol/mol vs 12 mol/mol). The composite flooding threshold of LiCl in silica gel is therefore lower than for $CaCl_2$ (Fig. 1b; e.g. 30.6 wt.% for B300 matrix). To verify these calculations, samples were tested in an environmental chamber at constant temperature and different relative humidity until salt leakage was observed. In addition, a thermogravimetric vapor sorption analyser was used to measure the water sorption-desorption isotherms of $CaCl_2$ and LiCl in silica gel composites. The flooding threshold can be observed as an inflection point in the adsorption branch and the initiation of hysteresis in the desorption branch.

ACKNOWLEDGMENTS

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CONFERENCE TOPIC

Solutions for Energy Efficiency
Excess Heat Energy and Resource Recovery from Low-grade Sources.

EVALUATING THE POTENTIAL FOR SOLAR DISTRICT HEATING WITH PIT THERMAL ENERGY STORAGE IN SWEDEN

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SUMMARY

A national analysis conducted in Sweden has concluded that the profitable potential capacity for solar district heating and PTES in Sweden is around 6 TWh, mostly in small DH systems where biofuels are used for baseload [1]. The result has sparked interest in solar district heating. A national project from the Swedish Energy Agency (2022-2024) aimed to explore the techno-economic-geological suitability of PTES with solar thermal collectors. This paper provides an overview of the project, methodological approach, and results obtained thus far in this project
Keywords: Solar district heating, pit thermal energy storage, geological analysis, techno-economic analysis, Sweden

INTRODUCTION

District heating (DH) is widespread in Sweden with nearly 550 system operating in major towns and cities. With many networks reaching end of life, the required system-wide upgrades can be pursued proactively to meet environmental targets and incorporate new technologies. With increasing variable renewable energy production, the general trend is that the single-source, fuel-based heating systems is transitioning towards flexible heating systems. These systems incorporate conventional heating sources (e.g., waste heat, biomass), emerging heating sources (e.g., data centres, heat pumps), renewable energy sources (e.g., solar thermal, photovoltaic etc.,), and interacts with other energy vectors (e.g., electricity, transport). The central element of flexible heating systems is energy storage, which facilitates interaction between multiple heat sources and user demand. Pit thermal energy storage (PTES) is the cheapest heat storage and has been commercialised largely in Denmark, Germany, China, and other countries. Sweden, has not seen any recent PTES installation, and the geological and technical suitability remains largely unknown.

OVERALL METHOD

The project involves two universities, one industrial partner and one international consultant. The principal research questions (RQs) under investigation in this project are shown in Figure 1. For RQ1, an updated list of Swedish district heating systems is compiled; data from which are used to calculate the collector area and PTES volume required across three different solar fractions (20%, 40%, and 60%). In the next step, a pool of case studies is subjected to screening to evaluate the suitability of geological conditions and the availability of land for the potential implementation of solar DH systems. The main objective is to narrow down to three promising case studies, for which system models are to be developed, followed by a techno-economic analysis (RQ2). To estimate the national potential to address RQ3, a geospatial analysis will be carried out using GIS that assimilates the learning obtained from the first two research questions.

PRELIMINARY RESULTS

In total, eight case studies are identified based on the contacts and interest from municipalities. The location of the analyzed case studies and their heating demand is shown in Figure 2. Table 1 shows the solar collector area and storage volume required to fulfill 20%, 40% and 60% of the annual heating demand. Each of the these case studies is analyzed for geological suitability for PTES installations. Parameters analyzed include soil depth, groundwater level, and flow, as well as soil type, and suitability. After geological filters, three case studies will be used for system modeling in TRNSYS for the techno-economic evaluation of the solar district heating system

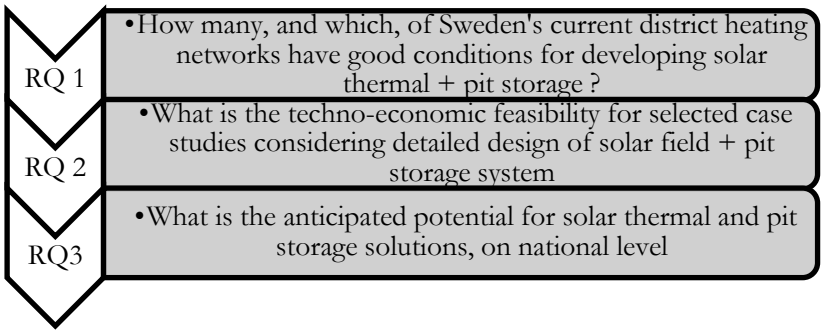

Figure 1. Research questions addressed in the project.

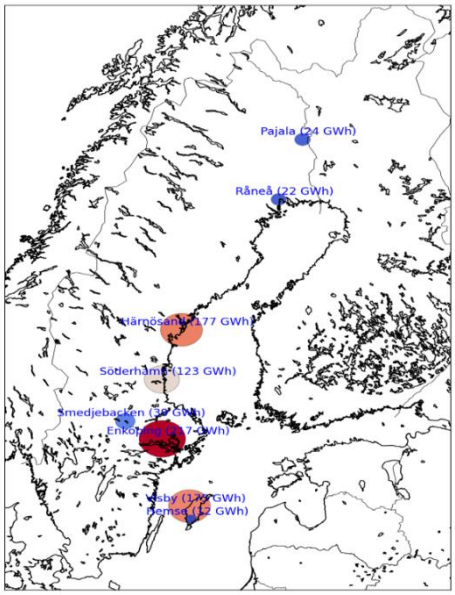

Figure 2. Heat demand, and geolocation of identified case studies.

Table 1. Solar collector area and storage volume for three different solar fractions (SFs) in selected case studies, which are screened for geological analysis.

	Solar collector area ($m^2_{aperture}$)			PTES storage volume (m^3)		
City name	**SF 20%**	**SF 40%**	**SF 60%**	**SF 20%**	**SF 40%**	**SF 60%**
Söderhamn	77000	155000	233000	19000	155000	467000
Visby	111000	222000	333000	27000	222000	666000
Råneå	13000	27000	41000	3400	27000	83000
Pajala	15000	30000	46000	3800	30000	92000
Hemse	8000	15000	23000	1900	15800	47000
Enköping	137000	270000	412000	34000	275000	825000
Härnösand	112000	220000	336000	28000	224000	672000
Smedjebacken	25000	49000	74000	6200	49000	149000

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CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications.
- Future District Heating and Cooling Technologies

DECARBONIZING PROCESS HEAT SUPPLY IN THE AUSTRIAN PHARMACEUTICAL INDUSTRY

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SUMMARY

In the pharmaceutical industry, energy efficiency has played a minor role compared to other energy-intensive industries. However, due to the ambitious climate targets and the resulting demands to drastically reduce CO_2 emissions, the pharmaceutical industry is now also feeling the pressure to significantly reduce its emissions. Fossil fuels are mainly used to provide process steam at moderate temperature levels at about 160-180°C and to a lesser extent to provide hot water or for on-site power production in CHPs. In this paper, the thermally relevant processes, such as for media supply, for cleaning or for room air conditioning, are presented and possibilities for increasing efficiency, for switching to alternative heat supply and for using alternative process technologies are evaluated with respect to economics, technological readiness but also regarding hurdles for implementation such as requirements for revalidation of production processes and possible necessity of re-approval of products.

INTRODUCTION

The driving motivation and background for conducting this study is the long-term reduction of greenhouse gas emissions in the pharmaceutical industry in the most economical way possible. Companies in the domestic pharmaceutical industry have ambitious targets and some companies want to be CO_2-neutral by 2025 considering scope 1 and 2 emissions. The manufacturing pharmaceutical sector in Austria is responsible for at least 1.5% (own calculation) of natural gas consumption in the domestic industry, with natural gas mainly used to provide process steam and heating. Typical energy supply systems in the production of pharmaceutical products are gas-fired steam boilers for the provision of process heat and chillers for the provision of the required cooling capacity for room climate and production. Steam from the boilers is used, among other things, in so-called black steam converters to generate pure steam, to heat water and alkalis in cleaning-in-place (CIP) systems, to generate water-for-injections (WFI) and pure steam, which in turn is used, for example, for room air conditioning, and in some cases for space heating. The energy input for CIP systems in dairy processes, for example, is about 9-26 % of the energy consumption [1]. A similar order of magnitude can be expected in the pharmaceutical sector. The inlet temperature of the media (caustic solutions, acids, rinsing water) is rarely higher than 80 °C, as this can jeopardize the stability of the media used [2]. For the U.S., the energy consumption of a drug manufacturing facility is distributed among space conditioning 65 % (HVAC), lighting 10 % and production 25 % [3]. By adjusting the air change rate to the rest periods, the energy consumption for clean room ventilation could be reduced to 40-45 % in a Turkish factory, for example [4].

Using alternative processes end technologies, temperature requirements and even energy demands can be reduced. The distillation of water is an energy-intensive process because energy is required for evaporation on the one hand and for hot storage on the other. However, WFI can also be produced by membrane filtration processes as which does not require heating at all. Using adiabatic humidification in HVAC systems could substitute currently used steam humidification, thus reducing the need for steam generation.

Additionally, heat recovery in the exhaust air system can reduce the process heat demand altogether. CIP systems also inhibit heat recovery potentials which can be exploited though buffering the processes warm wastewater to heat up media for the next CIP run. Alternatively, wastewater treated in neutralization plants can be used as a

source for heat recovery. The extensive use of refrigeration systems in the pharmaceutical industry yields large excess heat quantities at temperature levels of 30-40 °C which can be upgraded using heat pumps to supply hot water or even process steam at high energy efficiencies. Several processes used today could already be supplied through heat-pump powered hot water systems such as CIP-systems, room air heating, temperature control of tanks or defrosting processes. Some distillation processes (vacuum distillation) or drying processes can also be operated at relatively low temperature levels.
Even though the pharmaceutical industry yields large potentials for an increase in efficiency and for decarbonization, published work on these topics is sparse.

METHODOLGY

In this paper, the main consumers of process heat in the domestic pharmaceutical industry are presented and possible decarbonization alternatives are compared. These include measures to increase efficiency such as direct heat recovery, alternative heat supply, but also technology changes that either enable a change in heat supply in the first place, or directly reduce the heat demand. Alternative heat supply in this context means e.g. the use of green gases (biomethane, green hydrogen) in steam boilers, direct electric heating (e. g. e-boilers) or the use of heat pumps with different heat sources (waste heat, geothermal energy, solar thermal energy, heat grids).

EXPECTED RESULTS

In addition to a techno-economic analysis, a qualitative assessment is also given of how difficult process changes are to implement with regard to product approval and "change management". For example, a change in the fuel for steam generation is rather uncritical with regard to regulations and approval, whereas the change in technology for the provision of WFI may require a revalidation of the production process and a renewed approval of the product concerned in the respective markets.

AKNOWLEDGEMENT

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CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Solutions for Energy Efficiency
- Excess Heat Energy and Resource Recovery from Low-grade Sources

BIG SOLAR THERMAL PLANTS – A POSSIBLE GAME CHANGER FOR HEATING GRIDS AND INDUSTRY

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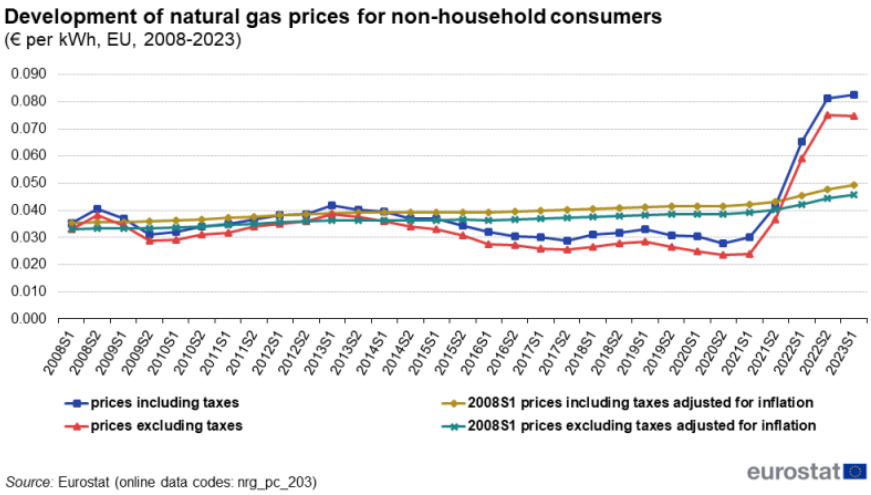
SUMMARY

The sharp fluctuations in the price of gas in 2022 led to an initial rethink on the part of large companies regarding the switch from fossil fuels to renewable energy sources. Triggered by an Austrian subsidy program, among other things, several feasibility studies were carried out in this area. The first projects are now being implemented. This article discusses experiences, lessons learned, the necessary framework conditions and the methods used to manage the changeover with the help of solar thermal combined systems.

INTRODUCTION

In view of the increasingly present climate crisis and the war in Ukraine, there is a strong desire everywhere to reduce dependence on gas and to primarily cover energy demand with renewable technologies. This trend is supported by the high uncertainty of gas prices (figure 1). Energy costs for natural gas have been largely stable at a very low level for more than 10 years. However, starting in the second half of 2021, the price of gas began to rise sharply. In the meantime, a price reduction has become apparent again, but the sudden and unpredictable price increase to more than double has shaken confidence in this energy source. Many companies have had to



recognize that long-term planning with gas as an energy source is fraught with great uncertainty.

Fig. 1: Price development of natural Gas für non-household consumers from 2008 to end of 2022 [1]

Another EU measure to reduce greenhouse gas emissions is CO2 pricing. A sharp price increase can also be seen in this area: since the beginning of 2020, costs have quadrupled from around €20/ton to around €83/ton [2].

REPLACEMENT TECHNOLOGIES FOR FOSSIL FUELS

If fossil fuels are eliminated, the only efficient and economical viable options left for heat supply are biomass boilers, deep geothermal, heat pumps and solar thermal. Biomass boilers can serve as a direct replacement for

fossil boilers and reach comparable temperatures, but this fuel is also limited, and regional availability is in-homogenous. In the area of heating networks, the temperature level that can be achieved with solar thermal energy matches the useful temperature level very well, which means that solar thermal energy can make a significant contribution to reducing fuel consumption. Full solar coverage of summer load has been implemented many times in smaller grids. Now operators of larger grids are beginning to take an interest. There are also initial initiatives in the industrial sector with process temperatures up to 150°C to make the heat supply completely renewable. One possibility is the use of concentrating solar thermal collectors, another system approach is the combination of solar thermal flat-plate collectors and high-temperature heat pumps.
The Austrian funding program for "solar thermal - large-scale solar plants", which has been known for many years, promotes the implementation of feasibility studies, especially in the field of grid integration and supply of industrial systems, which not only show the economic applicability of solar thermal, but also serve as a basis for decision-making for the implementation of the plants.
In the past 2 years, 33 studies have been awarded with a total gross collector area of 1,043,335 m² and a total contract volume of €2,067,081. The system sizes range from 5,022 m² to 400,000 m². Following the successful completion of the respective studies, the first plants are now beginning implementation. For example, an industrial plant with process temperatures up to 150°C will completely phase out gas using a system combination of 17,000 m² of PVT hybrid collectors, 20,000 m³ of water storage and 2.8 MW of high-temperature heat pumps. The overall system is supplemented with a 1 MWp photovoltaic system to further cover the electricity demand of the heat pumps.

In the work presented, the most important framework conditions for the conversion of fossil energy systems to renewable system concepts, the first steps towards implementation and the methods used are presented.

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CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Solutions for Energy Efficiency
- New technologies for realizing energy and resource efficiency (Process Intensification)
- Future District Heating and Cooling Technologies
- Replacement of big fossil Power Plants by Renewables – Impact on District Heating

NEW DEVELOPMENTS IN EFFICIENT PIT THERMAL ENERGY STORAGES FOR DISTRICT HEATING

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SUMMARY

The next generation of Pit Thermal Energy Storages (PTES) shall permanently meet the requirements of the European district heating network industry. The presented research project is therefore working in particular on topics such as advancing materials for higher long-term durability at 95 °C storage temperatures, inexpensive construction and operating methods, well-function and long-lasting floating covers, reliable and simple operation monitoring, and support of the market deployment through evaluated simulation models and simplified tools.

INTRODUCTION

To efficiently combining different renewable energy sources in district heating (DH) systems, large-scale thermal energy storages are a crucial component. The technology has been investigated in Europe since the middle of the 1970's in the context of cost-effective seasonal thermal energy storages for solar district heating systems (IEA DHC Annex XII, 2018). One construction method, which can be realized at a large-scale and at relatively low cost are Pit Thermal Energy Storages (PTES) like shown in Figure 1.

Figure 27: Pit Thermal Energy Storage in the solar district heating system of Gram, Denmark surrounded by ground mounted solar thermal collectors (Source: Fjernvarme Gram)

PTES are constructed as an artificial basin with a water tight high temperature resistant polymeric liner and insulating material on the cover and for some storages at the walls and the bottom. They are usually filled with water but can be also filled with water saturated gravel. The sizes range of some 100 m³ to more than 100,000 m³. Most of the existing PTES were built together with large-scale solar thermal installations integrated in DH systems in Denmark (Tschopp, et al., 2020) and some smaller ones in Germany (Solites, 2022). Thus a lot of experience is available, but there are some crucial research issues remaining:

- Long-time durability of the single materials built in the storage walls and cover under the real temperature conditions of the water of about 80 to 95 °C (Carlsen, et al., 2015) (IEA DHC Annex XII, 2018) (PITAGORAS, 2017).
- The implemented construction methods of the floating cover can be improved. The passage of water vapor from the hot interior of the storage partially condenses in the thermal insulation and reduces the insulating effect. The thermal insulation itself is not sufficiently pressure-stable at high temperatures and this water vapor exposure. The rainwater cannot be sufficiently drained from the storage cover, but must be extracted manually. (Fyhn, 2021) (Marstal Fjernvarme, 2014)

- The outgassing of the storage water, which is physically caused by the temperature increase, forms air bubbles under the storage cover. This causes overheating partial rise of the cover construction and thus influence to the cover structure.
- Possible leaks and their localization in the PTES are difficult to detect.
- The simulation of the effects of heat and mass transfer in the construction of a possible PTES can currently only be performed by a few experts (Ochs, 2008). There is a lack of a simple calculation tool.
- Several models in TRNSYS, Dymola, and the like are available for the simulation development of the system integration and sizing of a PTES. Some of the scientific work performed with these models shows large deviations for comparable boundary conditions (gigaTES, 2022). The reasons for these deviations have not been worked out at present.

GOALS OF THE RESEARCH WORK

In the public research project "Efficient Pit" (2021 to 2025), these issues are to be considered and solutions are to be found. The next generation of PTES shall permanently meet the requirements of the European district heating network industry. Therefore, the project aims at the following scientific and technical results:

- Development of a novel high temperature polymeric liner that can permanently withstand a temperature load of 95°C.
- Solutions for controlling the passage of water vapor through this liner, either with adapted component designs or with vapor barriers.
- New construction methods for economical thermal insulation not only of the storage lid, but also of the side walls and the storage bottom.
- Further developed, economical construction methods for the floating cover with an operating time of more than 20 years.
- Solutions for cost-effective, long-term operational control of the sealing and insulating function of the storage.
- Scalable construction methods or a construction series system for PTES between 10,000 and 500,000 m³ water capacity.
- Conceptual design tool for simple preliminary designs of large-volume PTES.

PLANNED ACTIVITIES

In order to find solutions for the research issues, the following activities are to be carried out during the project:

1. Laboratory tests on the function and ageing of temperature resistant polymeric liners and new system components are being carried out to further develop these materials so they can be used in PTES. According to the results the materials are being improved to fulfilling the requests mentioned above.
2. New design developments focus on coordinating interaction of single components including, for example, the use of thermal insulation in walls and bottom, the most economical and efficient geometrical shape of PTES, concepts concerning the dismantling of the entire structure and a new type of floating cover. In addition, a modular system for PTES from 10,000 to 500,000 m³ is being developed.
3. In order to be able to test the improved materials and designs under real conditions, a storage laboratory is being built at a production site. It is planned to consist of two pits with a volume of 3,500 m³ each and is operated with waste heat from a factory.
4. At the international level, the developments are being disseminated through participation in the IEA ES Task 39 LTES for DH (Large Thermal Energy Storage for District Heating) (IEA ES Task 39, 2022).

EXPECTED RESULTS

Development of the next generation of pit thermal energy storage, which permanently meets the requirements of the European district heating network industry.

The presentation will give an overview on the current needs on research for large-scale PTES in district heating based on results of the existing PTES. In addition, the presentation will show the latest results of the research activities in the research project described here. As the work is in progress, results are not yet published within this abstract. In the meantime until the conference, there will be results for example about the planning of the storage laboratory with its design aspects and the simulations of the water vapor diffusion in the floating cover.

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CONFERENCE TOPIC

Emerging heat and cold storage
Future District Heating and Cooling Technologies

Supported by:

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on the basis of a decision by the German Bundestag

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NEW DEVELOPMENTS IN HIGH EFFICIENCY BIOMASS HEATING PLANTS WITH ABSORPTION HEAT PUMPS.

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SUMMARY

Using Absorption Heat Pumps for Active Flue Gas Condensation is a success story in Austria with a couple of reference projects in the last decade.

In Q3 2023, the first demo plant of a new generation of these systems has been commissioned in Gerlos, Tyrol, proving that 105°C hot water can be sufficient as driving energy for the absorption heat pump. This is a major step forward, avoiding strict regulations from the Pressure Equipment Directive (PED) 2014/68/EU, which typically causes extra efforts and extra cost for the owners of the heating plants.

The system in Gerlos reaches a fuel efficiency of > 110%, based on the lower calorific value of W50 wood chips which are common in wintertime.

Experiences of the first heating season 2023/2024 will be presented and discussed.

Fig. 1: Gerlos heating biomass plant in the Austrian Alps, 1300 m above sea level.

KEY FACTORS

The main argument for using absorption heat pumps instead of compression heat pumps in biomass heating plants is quite simple: The driving heat is free of charge.
While electricity causes operating expenses for the heating plant, the absorption machine just uses the higher exergy level from the boiler. Standard systems are using steam or pressurized hot water at approx. 150°C.

Austria has > 2000 biomass heating plants and most of them are too small to bear the additional efforts of such 150°C standard systems. (Certification through a Notified Body, higher equipment cost, staff with training for the operation of steam boilers, etc…).
Ameliorating the fuel consumption of these heating plants with the new 105°C systems will safe huge amounts of biomass, which will be urgently needed for the ongoing de-carbonization of the heating sector.

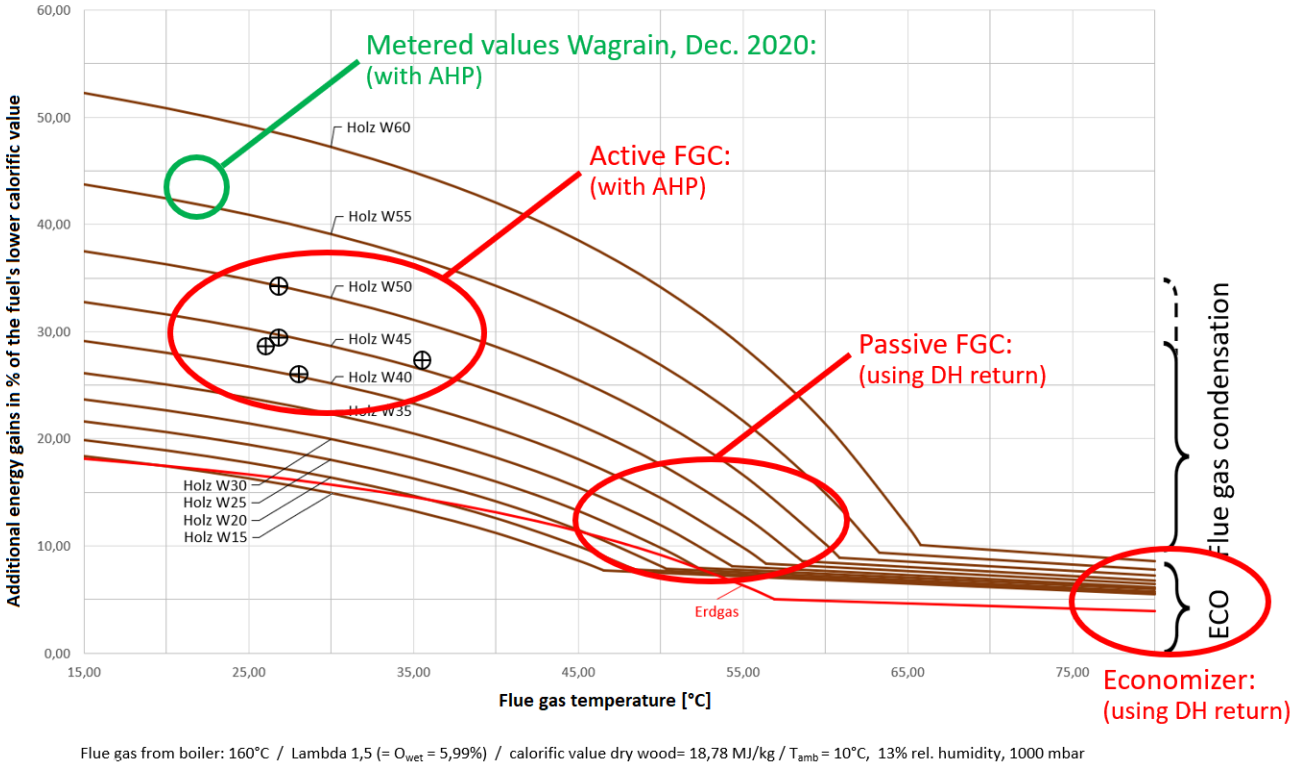

Fig. 2: Additional energy gains with Active Flue Gas Condensation

Beyond the operation experience from Gerlos, the potential of the development will be further analysed in the R&D project BM-Retrofit. https://greenenergylab.at/projects/bm-retrofit/

CONTENT DETAILS

The speech gives an introduction how aforementioned benefits can be reached.

- The principle of Active Flue Gas Condensation using LiBr heat pumps.
- The comparison of classical 150°C systems versus the new 105°C systems.
  Pros and Cons for both approaches.
- Project examples from 1,2 MW up to 24 MW heat pump size
- Discussion of financial aspects. What influences ROI and LCOE ?
- Success factors and lessons learned.

CONFERENCE TOPIC

Future District Heating and Cooling Technologies (or Solutions for Energy Efficiency, Excess Heat Energy and Resource Recovery from Low-grade Sources…)

LIFE CYCLE ASSESSMENT OF A SUSTAINABLE COLD, HEAT AND CLEAN WATER SYSTEM: SOPHIA CONCEPT

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SUMMARY

A cradle-to-grave Life Cycle Assessment (LCA) is carried out on a solar-powered cooling, heating, and clean water system for hospitals in Africa developed in the frame of the EU-funded project SophiA. Two impact assessment methodologies were used (Global Warming Potential "IPCC 2021 GWP 100a" and the Product Environmental Footprint 3.1). The innovative SophiA systems were built and commissioned in South Africa and will be operational in January 2024 in Leo Hospital in Burkina Faso. LCA results are compared with a conventional diesel system and a grid-based system. The results show that the SophiA system reduces the environmental impact by 50% when compared to the grid-based system. In general, it can be concluded that the proposed SophiA system is an alternative to reduce the environmental impact in all the considered solar irradiance levels and electricity mix scenarios, even in climates with low irradiance levels or in countries with a highly decarbonised electricity supply.

INTRODUCTION

The SophiA project will enable beneficiary hospitals and health centres in Africa to access carbon-neutral energy for cooling medicines and heating purposes, as well as clean, virus-free drinking water and demineralised water for steam production and various medical applications. SophiA is developing and locally manufacturing an innovative, modular, flexible, affordable, and efficient solar-powered containerized system to provide local populations in rural health centers from different climatic regions with sustainable solutions adapted to the African context and then transferable to the whole of sub-Saharan Africa. The SophiA systems will be demonstrated at four health facilities in Burkina Faso, Cameroon, Malawi, and Uganda.

The two solar-powered, modular container solutions can be easily integrated into existing infrastructure. Using natural refrigerants, the SophiA cooling container will provide low and ultra-low temperature storage for blood plasma and sensitive drugs [-30°C] [-70°C] and cooling for surgical or intensive care units, medicines, and food [+5°C]. Using PV, solar thermal and Scheffler reflectors, SophiA water containers will provide drinking water and pure water for medical purposes, steam for sterilization, and solar cooking as well as hot water.

METHODOLOGY

Life Cycle Assessment (LCA) is a comprehensive method, that collects all material, energy, and emission flows related to a product or a service like the provision of MJ heat or cold of a specific quality. These flows are then grouped according to the potential harm they may impose on ecological systems or individuals, and the impacts related to e.g., climate change, toxicity, acidification, and ozone depletion are quantified. So-called “direct” emissions and other burdens are caused by the operation of heat or cold generation units, while “indirect” emissions and other burdens are caused by processes in the energy chain (e.g., fuel or material supply) as well as consumption of fuels, electricity, materials, and transport services for all processes within the energy chain. The latter are so-called “background processes”, which are taken from a background LCA database like Ecoinvent (Wernet 2019).

This LCA is performed according to the ISO standards with appropriate system boundaries and methodological choices adapted to each application and a geographical focus on the South African region (ISO 14040 2006; ISO 14044 2006). Calculations were done with SimaPro.

GOAL AND SCOPE DEFINITION

The general objective of this LCA study is to investigate the environmental performance of the raw material extraction and manufacturing processes of the SophiA system, as well as the environmental impacts associated with its use and end-of-life phases. Thus, the following research questions were analyzed:

- What are the specific environmental impacts associated with the life cycle of the SophiA system from cradle to grave?
- Which activities during the life cycle of the SophiA system are responsible for the greatest environmental impact?
- What possible improvements could be made to enhance the environmental performance of the SophiA system?
- How well does the 100% renewable-driven SophiA system perform from an environmental point of view compared to a fossil fuel-powered or grid-powered system?

SYSTEM BOUNDARY AND FUNCTIONAL UNIT

The SophiA system fulfills multiple functions by continuously providing renewable, off-grid refrigeration at different temperature levels (-70 °C, -30°C, 5°C), heat (warm water/steam), and freshly cooled water to various hospitals in Africa, without disruption or power outages. Fig. 5 illustrates the system boundary of the SophiA system with its functional units.

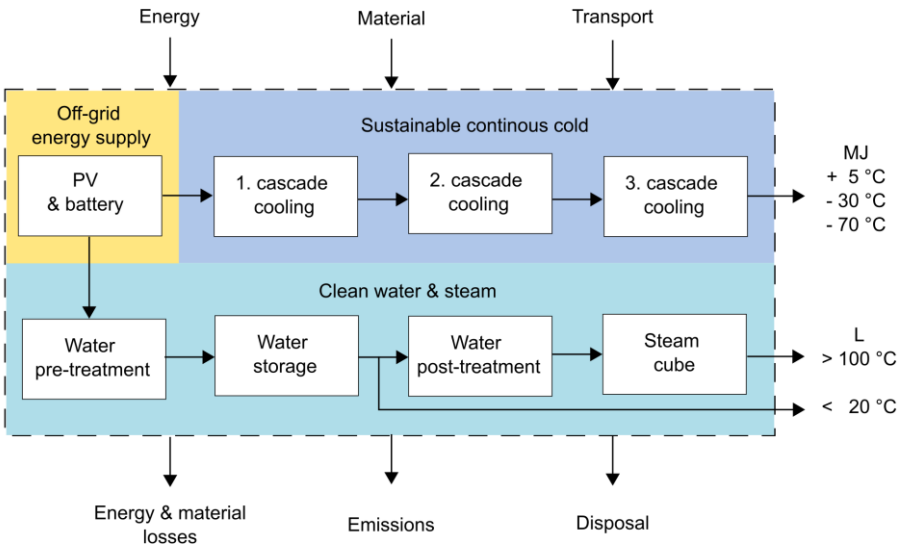

Fig. 5: System boundary of the SophiA system including its two-container providing sustainable continuous cold, heat, and clean water.

Various load profiles were simulated based on the operation in Burkina Africa, in line with the real-life application in the field. The end of life was set at 25 years, taking into account the material requirements for repair and maintenance of the whole system.

LIFE CYCLE INVENTORY (LCI)

Project-specific data was directly obtained from internal partners via direct communication, deliverables, and questionnaires. Where applicable, Ecoinvent 3.9 reference data sets have been used to model the components of the SophiA system.

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CONFERENCE TOPIC

Renewable heating and cooling, including high-temperature applications.

PREDICT-IT: FORECASTING DISTRICT HEATING LOADS WITH AN OPEN-SOURCE AND USER-FRIENDLY NEURAL NETWORK-POWERED PLATFORM

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SUMMARY

District heating operators collect usage data of their customers, but do not always use it to the fullest extent. One application of such measurement data is to predict the required heat load in the network from past data, making the prediction independent of expert knowledge. Such a forecast can lead to more efficient usage of the plant infrastructure like boilers or heat storages. In this work, we introduce the web-based platform “Predict-IT": This platform standardizes the pipeline including data upload, prediction of heat load, and visualization of the generated forecasts. The platform is fueled by a state-of-the-art LSTM-based neural network algorithm, delivering very good prediction results of the future heat load. Using the Predict-IT platform, creating forecasts is straightforward, as only one input variable (the measured heat load) is required. Furthermore, the source code is open source, and deployment and installation are facilitated by an easily installable Docker solution.
Keywords: Heat load prediction, LSTM-based neural network, Web-based platform, Open-source software

INTRODUCTION

Predicting the heat load of a district heating plant is an active research area, see e.g. (Cui, 2022; Dang et al., 2023). The focus of most papers lies on the prediction algorithm itself. In contrast, in this paper we not only use state-of-the-art algorithms for the prediction, but also provide a web-based application that wraps the core algorithm and makes it straightforward to deploy the prediction in a specific plant. To enhance broad applicability, Predict-IT is independent of the plant control system and only requires uploading the total heat load data including time stamps to predict future heat loads. The prediction algorithm also uses weather data which are retrieved automatically, for the given plant location. The software can be deployed and installed using a Docker container, and the application will be licensed under an open-source software license. In addition, Predict-IT enhances the efficient utilization of heating resources and reduces reliance on expert knowledge for heat load predictions. The data-driven, standardized approach diminishes the impact of staff fluctuations, ensuring a more stable and reliable operational framework.

METHODOLOGY AND TECHNOLOGY

The basis for the prediction is the plant total heat load, as recorded by the control system. The extraction and upload of the data are followed by two pre-processing steps: The first step brings the data into a unified format (e.g. time stamps, units), the second step does algorithm specific preparations (e.g. normalizing, handling of missing values, preparing sub-samples). Finally, data are split into a training and a test set to train and evaluate the algorithm. The best-performing algorithm version is stored to be used on future data. The data flow diagram is shown in Fig. 1.

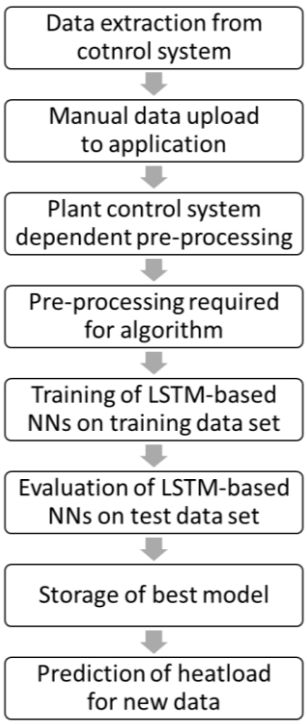

Fig. 1: Data flow

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For predicting heat loads several algorithms have already been used: On the one hand, ARIMA/SARIMA models, which model the dependencies among the variables over time based on statistical approaches, and on the other hand, machine learning algorithms such as boosting algorithms and support vector regression, which are not specifically designed for time series data, see e.g. (Dang et al., 2023; Grosswindhager et al., 2011). We use state-of-the-art long-short-term-memory (LSTM) based neural networks (NN), since they are designed for time series data and can model complex dependencies (Cui, 2022; Yu et al., 2019). Our model takes as an input the heat load from the previous days and predicts the heat load for the coming hours or days, as specified by the user, based on ambient temperature, using local weather data. The advantage of LSTM-based NNs is that they can represent more complex systems, however, require longer training times (compared to the other approaches).
Regarding the used technology, the data processing and model learning are implemented in Python using Tensorflow (Abadi et al., 2016). To make the results available, a platform is implemented using the state-of-the-art web framework Django (https://docs.djangoproject.com/). Furthermore, a Docker-solution for packaging the algorithm and all required components for simple deployment is aimed for (https://docs.docker.com/).

RESULTS

The LSTM-based NN was evaluated on a data set, consisting of measurements for 3 years, of a typical local district heating network with only private households as customers. The algorithm was trained on half of the data set. As input, the algorithm received three days of heat load measurement data resampled to 20 minutes to predict the following three days based on the measured ambient temperature. The prediction results are summed up to hourly values to reduce noise. The model was trained for about 10 minutes on a NVIDIA Quadro P2000 graphics card. Fig. 2 shows two representative examples from the test set. The predicted heat loads (green line) are very close to the true ones (orange dashed line), confirming the good fit of the model.
The Predict-IT platform guides the user through the required steps to set up a prediction for a specific plant (see Fig. 3): First, settings like plant location (for weather data) and prediction horizon (e.g. predictions for the coming 12 hours or 3 days) have to be entered. Secondly, measurement data must be uploaded, with specified column separator or format. The measurement data are pre-processed in the background. On a pre-trained algorithm, the heat load prediction is made in real-time and visualized. If the model has not been trained yet, model training is done in the background before generating the heat load prediction.

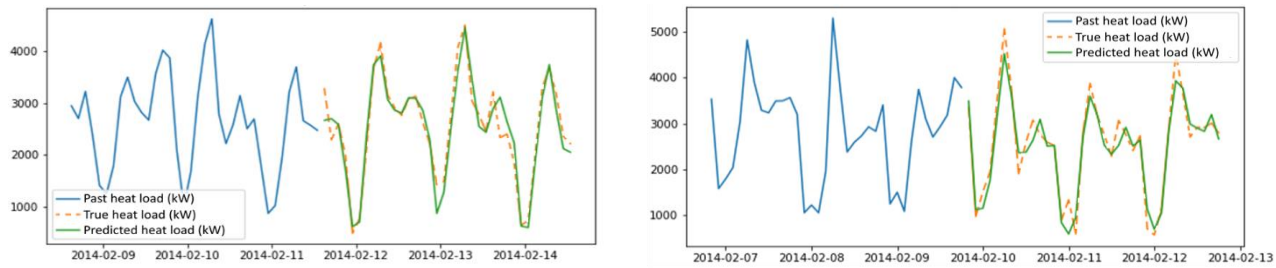

Fig. 2: Results of algorithm prediction: In blue the network input, in orange the true values and in green the predictions.

DISCUSSION AND CONCLUSION

The LSTM based NN performs very well on the test data delivering accurate heat load predictions up to three days into the future based on ambient temperature. This algorithm builds the basis for providing heat load predictions to plant operators. There are three crucial points for the wide and easy applicability for plant operators:

1) Data upload: Since the algorithm only requires heat load time series data, initial data preparation for the plant operator is limited to providing this variable which is typically available for heating networks. Additionally, the step of control system-dependent data pre-processing has already been automated for the data formats of two leading Austrian providers of plant control systems.

2) Training of the NN: The training time of our NNs depends on the model complexity (i.e., number of hyperparameters) and can range from several minutes to hours, such that the initial training can be done, e.g., overnight. Within the platform, two measures are taken to limit the training time: a pre-defined set of standard hyperparameters is given, based on previously executed experiments, and re-training strategies are tested to evaluate when to retrain the complete model (time-intensive) and when to only finetune the model (time-efficient). An option for improved training performance is to conduct model training on the computer's graphics card, leading to a significant speed-up in training time.
3) Usage of the platform: The application will be made available under an open-source software license (details to be determined), and the deployment is realised using Docker.

To test the Predict-IT system in real life and to obtain feedback from an operator, we are planning to deploy the platform at a district heating plant. Furthermore, there are several directions of future work. Currently, the data upload must be done manually. If the plant control and the technical plant setup allow it, the data could be extracted automatically or even transferred to our system in real time. Regarding the algorithm, the training and testing is currently done using historic ambient temperature data, as opposed to forecast data. The latter approach introduces additional model uncertainty, and it is yet to be seen how the model can handle this step.

Overall, the Predict-IT platform and the introduced algorithm deliver reliable results for the task of heat load prediction. The solution is independent of the plant control system and is easy to install (based on Docker) and to use (via the web interface). Predict-IT will be made available under an open-source software license.

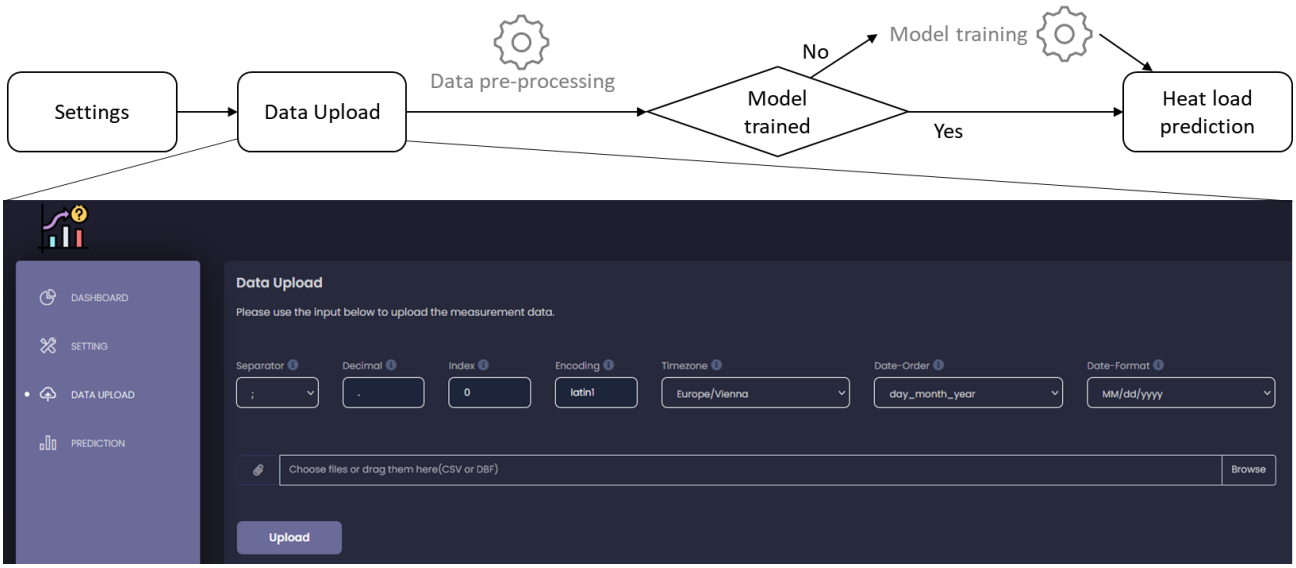

Fig. 3: Usage diagram with the upload view of the Predict-IT platform. The steps in grey letters run in the background.

ACKNOWLEDGEMENT

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications; Digitalization for Future Energy Systems; Future District Heating and Cooling Technologies; IT Technologies and Artificial Intelligence; Smart Services and System Operation

ENABLING ICT ENVIRONMENT FOR DESIGN AND OPERATION OF 4TH AND 5TH GENERATION DHC GRIDS

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SUMMARY

The goal of HYPERGRYD is the development of a set of replicable and scalable cost-effective technical solutions to allow the integration of Renewable Energy Sources (RES) with different dispatchability and intrinsic variability inside thermal grids as well as their link with the electrical grids, including the development of innovative key components, in parallel with innovative and integrated ICT services formed by a scalable suite of tools for the proper handling of the increased complexity of the systems from building to Energy Community (EC) levels and beyond, and accelerate the sustainable transformation, planning and modernization of District Heating and Cooling (DHC) towards 4th and 5th generation.

INTRODUCTION

The goal of the HYPERGRYD project is the development of a set of replicable and scalable cost-effective technical solutions to allow the integration of Renewable Energy Sources (RES) with different dispatchability and intrinsic variability inside Thermal Grids as well as their link with the Electrical Grids, including the development of innovative key components, in parallel with innovative and integrated ICT services formed by a scalable suite of tools for the proper handling of the increased complexity of the systems from building to Local Energy Community (LEC) levels and beyond, and accelerate the sustainable transformation, planning and modernization of District Heating and Cooling (DHC) towards 4th and 5th generation.
HYPERGRYD also aims at developing real time management of both electrical and thermal energy flows in the coupled energy network complex, including the synergies between them. Therefore, HYPERGRYD aims at three over-arching General Objectives:

- To prove Smart Energy Networks as the future of Efficient Energy Management in DHC in synergy with the Electrical Grids in LEC/Smart Cities of the future.
- To define the roadmap to design and plan future DHC as well as the modernization of the existing ones in different climates and RES penetration levels toward 4th-5th generation,
- To demonstrate HYPERGRYD RES-based Enabling Technologies, Smart Energy Grid Solutions empowered by new ICT tools and services as the key for this evolution.

During the project, the HYPERGRYD's solutions will be implemented across four Live-In-Labs cases in three representative climates, with special consideration to their cost effectiveness and potential replicability to finally achieve these three main objectives.
This abstract aims at presenting the overall project and list the main exploitable results identified in the first two years of the project's lifetime. Those exploitable results within HYPERGRYD could take one of two paths in the future:

1. been buried in the "graveyard of good ideas" or;
2. reach a meaningful impact, whether is via market uptake or via further research with an exploitation strategy defined.

THE LIST OF EXPLOITABLE RESULTS

Table 1: List of exploitable results detected in HYPERGRYD

#	Exploitable Result	Type
ER1	Sorption Thermal Energy Storage	Product
ER2	Modular Heat Pump with short-term PCM storage	Product
ER3	WPW (water-PCM-Water) heat exchanger	Product
ER4	Reversible micro-CHP with steam engine and steam buffer	Product
ER5	BIM-GIS toolkit for DHC network piping and configuration planning	Product
ER6	Exergoeconomic optimization tool for 4th and 5th generation of DHC	Model
ER7	SAInt - Scenario Analysis Interface for Energy Systems	Software
ER8	Grid Singularity Exchange (local energy marketplace tool)	Software
ER9	HYPERGRYD Digital Twin Platform as a Service	Product
ER10	Optimization-based demand response algorithms for sector coupling.	Software
ER11	Machine learning-based models for load prediction in buildings	Model
ER12	Integrated framework for services in SED/LEC enabled by DHC networks	Knowledge
ER13	Edge IoT tool for the optimal operation of heat pumps within a local energy network	Product
ER14	Novel stacked energy and engineering services for DHC networks/assets	Service
ER15	GIS-BIM compatible DHC network piping and configuration planning	Software
ER16	Software enhancements of open-source Grid Singularity Exchange (GSyE)	Software
ER17	LCA and LCC model for RES in DHC networks	Model + Knowledge
ER18	HYPERGRYD user-friendly interface	Software
ER19	HYPERGRYD enhanced Business model	Knowledge

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SOLAR TECHNOLOGIES TOWARDS ACCELERATION OF SOLARHUB GREEK-TURKISH ECOSYSTEMS

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SUMMARY

This work describes the four solar predesigns developed in the framework of the SOLARHUB European project. These predesigns stem from the overall SOLARHUB strategy that promotes Green Deal priorities, strengthens and exploits the competitive advantages of the Greek and Turkish ecosystem through the organization of joint R&I activities that promote academic-business linkages. The four predesigns employ solar technology, in the form of solar heat and electricity production via photovoltaic panels, target at agricultural and industrial applications and consist of 1) Pre-design of solar thermal solution for low temperature (up to 120°C) heat applications 2) Pre-design of solar-aided hydrothermal treatment solution for agri-food residual products 3) Pre-design of PV solution for power production and micro-climate creation for tree plants and 4) Pre-design of PV solution for efficient crop production through light and water management.

Keywords: Solar technologies, Solar thermal, Photovoltaics, Green Deal

INTRODUCTION

SOLARHUB's overall objective is to strengthen connections between and scale-up five Greek and Turkish solar energy innovation ecosystems as a single, hybrid, cross-border, and interconnected Solar Energy Excellence Hub with an emphasis on agriculture as main application area. SOLARHUB's four Specific Objectives (SOs) are explicitly framed by five core components and target the expected outcomes and impacts. These SOs are to a) Co-develop a Hub Strategy and a Joint Strategic Research & Innovation Agenda b) Execute a diverse set of complementary interventions, engaging all players of the quadruple helix to support R&I and accelerate commercialization c) Implement joint R&I activities to develop four pre-designs of diverse solar energy solutions d) Maximize the project's impacts through dissemination, exploitation, and communication activities carefully tuned to actively engage all players of the quadruple helix. To achieve these objectives, a diverse and complementary set of measures are planned that include a) Creation of relevant R& I strategies & policies b) Networking between SOLARHUB & stakeholders c) Multi-level engagement & training e) Combination of R&I infrastructures for synergies d) Creation of targeted joint programmes and linkages between the 2 countries based on sound technological solutions e) Communicating the above to all major stakeholders in the targeted regions and application areas f) Exploiting the positive results from all the above to setup a sustainable collaborative initiative after the end of the project. SOLARHUB's consortium is well-balanced between Academia and Business and fully completes the quadruple helix (academia, business, public authorities, societal actors). SOLARHUB efficiently exploits the consortium's diverse knowledge and expertise to develop Green solutions to selected current Societal Challenges.

This work discusses the technical and operational characteristics of the four predesigns, included in the Specific Objectives of the SOLARHUB project. The four pre-designs are as follows:

- Solar thermal solution for low temperature heat applications: This predesign refers to a scalable and replicable solar thermal system constituted of high efficiency flat plate collectors for heat production at 80-120ºC, a heat storage tank utilizing low cost and abundant ceramic materials, a smart system control for efficient energy management and a dimensioning tool.
- Solar-aided hydrothermal treatment solution for agri-food residual wastes: The second predesign addresses hydrothermal/high pressure processing of agri-food/livestock residual wastes to produce bio-oil. The system employs solar heat at 500-600ºC to drive the thermochemical process and efficient reactors for the hydrothermal treatment. High temperature solar heat is produced through a particle receiver design that can also act as thermal energy storage medium during no solar irradiation.
- PV system for power production in tree cultivation fields: In the third pre-design, a fixed tilt support structure that supports semi-transparent PV modules is foreseen. The design of this system is such that allows unobstructed installation in tree fields of relatively high height such as peaches. The design focuses on the combined use of land, both for energy production and crop cultivation, and studies the optimization of the dual use. Light management, protection from extreme weather conditions, space allowance for workers and machinery are also considered.
- PV system for power production in low crop cultivation fields: The last pre-design refers to a scalable and replicable agri-PV system designed for low height crops. Light and shading management is included in the form of spectrum and intensity control and adjustment of the module transparency, according to the crop type and needs. Additional properties of this predesign are the rainwater management and the monitoring of the weather and soil conditions.

CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Solutions for Energy Efficiency
- Coupling of Energy Sectors

REVIEW ON THE RENEWABLE HEATING AND COOLING PLANS IN CROATIA, GERMANY, GREECE, POLAND AND PORTUGAL

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SUMMARY

This work presents the results of the REDI4Heat European project, regarding the assessment of the National Climate and Energy Plans NECP and the renewable heating and cooling RHC support mechanisms for 5 EU Member States; HR, DE, EL, PL and PT. The study begins with the presentation of the latest NECP revised targets in the heating and cooling sector and more specifically, in the use of solar thermal energy, geothermal heat pumps, district heating and cooling networks, biomass boilers and heat pumps. Then, the progress of each Member State against their specific national targets will be analysed and evaluated. The opportunities and barriers for the further deployment of the RHC technology in each MS will be also identified, with the view to provide recommendations on the implementation of the policy framework towards decarbonisation.

Keywords: National Energy and Climate Plans; Renewable Energy Directive; renewable heating and cooling; decarbonisation.

INTRODUCTION

Heating and cooling represents 50% of the energy demand in Europe and 80% of the energy consumption in households. The decarbonisation of heating and cooling is essential for the decarbonisation of the whole energy sector and constitutes a major challenge that needs to be urgently addressed. The Clean Energy Package introduced several measures aiming at increasing considerably the uptake of renewable heating and cooling solutions until 2030. Most Member States have yet to design strategies for the heating and cooling sector that are ambitious and effective enough in order to comply with the Renewables Directive, namely Article 23. The purpose of REDI4HEAT European project is to support the implementation of the RED provisions on heating and cooling and assist five Member States and their local authorities in that process. It will provide a better understanding of the shortcomings in current strategies and propose to address these with a set of recommendations, which shall include Strategic Policy Priorities for Heating and Cooling, Policy Adoption Scenarios, best practices, among other. This work is valuable for the national energy agencies, policy actors, local authorities and energy consultants.

REVISED NECPS AND TARGETS IN HEATING & COOLING

This chapter will communicate the recently revised NECPs in the five target MS and will discuss the new targets regarding heating and cooling sector, renewables uptake and energy efficiency.

Croatia

General discussion on Revised NECP, comparison between NECP2019 and NECP2023

Current targets in energy efficiency

Current targets in heating and cooling
Current targets in specific technology; solar thermal energy, geothermal, district heating and cooling, biomass, heat pumps

Germany
General discussion on Revised NECP, comparison between NECP2019 and NECP2023
Current targets in energy efficiency
Current targets in heating and cooling
Current targets in specific technology; solar thermal energy, geothermal, district heating and cooling, biomass, heat pumps

Greece
General discussion on Revised NECP, comparison between NECP2019 and NECP2023
Current targets in energy efficiency
Current targets in heating and cooling
Current targets in specific technology; solar thermal energy, geothermal, district heating and cooling, biomass, heat pumps

Poland
General discussion on Revised NECP, comparison between NECP2019 and NECP2023
Current targets in energy efficiency
Current targets in heating and cooling
Current targets in specific technology; solar thermal energy, geothermal, district heating and cooling, biomass, heat pumps

Portugal
General discussion on Revised NECP, comparison between NECP2019 and NECP2023
Current targets in energy efficiency
Current targets in heating and cooling
Current targets in specific technology; solar thermal energy, geothermal, district heating and cooling, biomass, heat pumps

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National energy and climate plans (NECPs) https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en
Draft updated NECPs in 2023 https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#national-energy-and-climate-plans-2021-2030
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Renewables 2023 Global Status Report https://www.ren21.net/reports/global-status-report/

CONFERENCE TOPIC

This abstract refers to:

- Policies and/or
- Renewable heating and cooling, including high temperature applications.

FINANCING SCHEMES FOR GEOTHERMAL DHC NETWORKS

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SUMMARY

With the planet heating faster than predicted, decarbonizing the largest emitting sectors, such as heating and cooling (H&C) becomes even more pressing. District systems hold a great potential to decarbonize H&C. Studies estimate that to achieve the EU 2050 climate targets, District heating and cooling (DHC) might grow from the current 7% of H&C supply in buildings to up to 30%-40%. Geothermal is likely to be among the main renewable energy source of DHC, growing from 2.5% to up to 16-18% of the DHC energy mix in some countries. However, both technologies still face significant financial barriers due to their capital-intensive nature and peculiar risk profile. In the effort to help lowering those barriers, the H2020 project SAPHEA mapped current public and private financing schemes at the EU and national levels in a database and derived in a status report the most significant trends and indicators. This paper presents the key outcome of this work. Keywords: financial barrier, mapping financing schemes, geothermal, district heating and cooling, decarbonize H&C

INTRODUCTION

The most recent research shows how climate change is accelerating faster than previously estimated and global warming is heading to catastrophic levels unless drastic measures are implemented (Hansen et al. 2023; IPCC 2023). In this view, it becomes mandatory to decarbonize the most emitting sectors, such as heating and cooling (H&C), responsible for half of the energy consumption and emissions in the EU. Among the promising solutions, District Heating and Cooling (DHC) networks emerge as a pivotal component to decarbonize this sector, offering vast potential to improving energy efficiency and reduce carbon footprint. Estimates show that DHC might grow from the current 7% of H&C supply in buildings (Figueira, Goetzl, and Schifflechner 2022) to up to 50% by 2050 (Euroheat & Power 2023). The DHC potential to decarbonize H&C is even greater when coupled with low-carbon energy sources. Geothermal energy is likely to be among the main energy sources of DHC, growing from 2.5% to up to 16-18% of the DHC energy mix in some countries, e.g., France (Euroheat & Power 2023).

DHC offers several advantages (Schmidt and Leitner 2021): it allows significant reductions in primary energy consumption, provides affordable and reliable heat, allows to decarbonize the heat supply without counting on individual action, resulting in increased indoor comfort with higher efficiency and lower emissions, alleviated energy poverty and reduced heat island effects. Geothermal energy is abundant and widely available, it can be harnessed virtually everywhere, offering a reliable and continuous source of carbon-neutral thermal energy that paired with heat pumps, can supply both heating and cooling. Nonetheless, a fast and wide uptake of geothermal DHC is hindered by significant barriers. DHC is capital-intensive, requiring substantial infrastructure and construction investments (Pinna et al. 2020). Geothermal energy has a distinct risk profile, facing high exploration risk before the first drilling can confirm its success. Innovations like closed loop and shallow geothermal can help addressing these challenges, but in general financing is a major barrier for both technologies.

To help unlock the full potential of DHC and geothermal energy to deliver a low-carbon future, this work presents the assessment of existing public and private financing schemes for geothermal energy in DHC systems, based on the mapping carried out in the H2020 project SAPHEA and presented in its Status Report (D4.2). First, the

methodology used in the mapping and assessment is illustrated. The result of the mapping is compiled in a database on which an analysis identifies the most common schemes and the countries offering the most and least financial support to these technologies. The main outcomes are then summarized in the findings and results.

METHODOLOGY

A literature review collects existing publications on financing schemes for geothermal energy in DHC systems. Existing databases and relevant results from previous projects are updated through the literature review and desk research for the EU level and each MS country. Instruments are listed with their features: country, geographical level, targeted sectors, type of building, type of financial instrument, links, timeframe, and a short description. Country experts in various projects are consulted for feedback, to identify missing schemes as well as correct inaccuracies. A few analyses are run on the database to reveal the most and least common instruments, the countries offering the most and least support, as well as other significant indicators.

FINDINGS AND RESULTS

The whole mapping is gathered in a database, from which significant regional diversity can be seen. Several schemes for H&C are not applicable to DHC. DHC is often subsidized more for recovering and using waste heat from industrial processes than to be supplied by renewable energy. Renewable energy subsidies rarely mention explicitly geothermal. Regional differences are visible, reflecting the level advancement of DHC across countries. It is interesting to note which type of financial instruments are most frequent and how this reflects the perception and priority not always given to DHC compared to other solutions to decarbonize the building stock. New technologies such as closed loop and shallow geothermal significantly reduce the risk of unsuccessful geothermal projects at the price of more expensive drilling costs, paving the way for a broader uptake of the geothermal resource in general and in DHC systems. However, the capital-intensive nature of geothermal and its peculiar risk-profile remain a barrier and still discourage a faster expansion of this resource. Public subsidies and favourable policies might help lower such barrier.

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CONFERENCE TOPIC

This abstract refers to the following Conference Topics and cross-cutting themes:

- Renewable heating and cooling, including high temperature applications
- Future District Heating and Cooling Technologies
- Replacement of big fossil Power Plants by Renewables – Impact on District Heating
- Policies
- Finance and Business Models

NEURAL NETWORK TO GENERATE SYNTHETIC ELECTRICAL LOAD PROFILES

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SUMMARY

Data has become a powerful catalyst for change. The ability to collect, analyse and share data in the building sector can open new opportunities for optimization, efficiency, and sustainability. Nevertheless, due to privacy concerns, companies are unable to share costumer meter data. Synthetic data provides a valid alternative to the use of real data, since the data is anonymized and maintains original statistical characteristics. In this paper, we will frame synthetic data in the European project MODERATE and its application within the building field. First, we will discuss its benefits and challenges. Then, we will illustrate a specific use case, where we generated synthetic load profiles with two deep neural network algorithms of the GAN family.

Keywords: synthetic data, GAN, deep neural network, AI and building

SYNTHETIC DATA: BENEFITS AND CHALLANEGES

In the last years, the use and generation of synthetic data has advanced across several sectors from banking to health and, not lastly, the building and energy sector. Synthetic data is artificially generated data that retains the statistical characteristics of the real data without containing any identifiable information. This makes synthetic data extremely powerful to safely share data across organizations and use it in the implementation of analysis and ML algorithms. In the building sector, the utilization of synthetic data has gained significant traction in recent years and has the potential to revolutionize how buildings operates (Yilmaz and Korn, 2022), (Baasch et al., 2021), (Pinceti et al., 2021).

The European funded project MODERATE[5] aims to fill the gap of shortage of shared data in the building field and publish an open synthetic dataset and data-driven services to improve the analysis of building performances. Synthetic data offers a range of benefits. First of all, it helps to mitigate privacy concerns and provide a safe environment for testing, sharing and analysing. This facilitates knowledge transfer and collaboration. Data can be safely shared without exposing sensitive information to third parties. As cascade effect, it accelerates innovation. Users can implement technologies and methodologies at a quicker pace. Moreover, synthetic data enhance data quality and control and provide robust data inputs for analysis and modelling.

Nevertheless, the process of generating synthetic data comes with legal and technical challenges. The primary challenge revolves around the release of private data while maintaining confidentiality and intellectual property rights. Companies hesitate to share sensitive information with externals parties, and entities possessing the expertise to generate synthetic data often face the challenge in accessing to the original data. The second challenge is technical and involves capturing data complexity, efficiently generating synthetic data for large-scale datasets and generating high-quality synthetic data in a timely and cost-efficient manner. Overcoming the above-mentioned limitations requires advancements in machine learning and data generation methodologies and interdisciplinary collaborations between the different experts.

In the next paragraph we present the workflow and the methodology used, but also the technical challenges encountered when generating synthetic load profiles in one of our caser studies.

[5] https://moderate-project.eu/

USE CASE: SYNTHETIC ENERGY LAOD PROFILES

We analyzed 393 electrical load profiles over an 18-month period, with hourly data points. Due to privacy concerns, we only had access to electricity consumption and timestamps, lacking metadata such as building type or location. This posed a significant challenge in data classification. To compensate, we conducted feature engineering to classify short and long-term consumption trends. Extracted features included details like seasons, weekdays, workdays, statistical metrics, like dispersion and central tendency peaks, and zero-consumption periods.

To generate synthetic load profiles, we opted for Generative Adversarial Networks (GANs) algorithms. GAN belongs to the family of deep learning methods and since its introduction in 2014 (Goodfellow et al., 2014), it has shown tremendous capabilities and potential to create realistic-looking images and generate synthetic data. The architecture consists of two neural networks, a discriminator (D) and a generator (G). engaged in competitive training. Over time, the generator becomes proficient at creating synthetic data that is difficult for the discriminator to distinguish from the real. We tested two different algorithms: DoppelGANger and Conditional GAN. DoppelGANger was introduced by Li and colleagues (Lin et al., 2020) specifically to capture time series dependencies and to integrate metadata in the architecture with the final results of achieving up to 43% better fidelity than baseline models. However, since the only metadata information we had come from feature engineering process, DoppelGANger resulted to be useful when generating profiles not longer than a day (Figure 28).

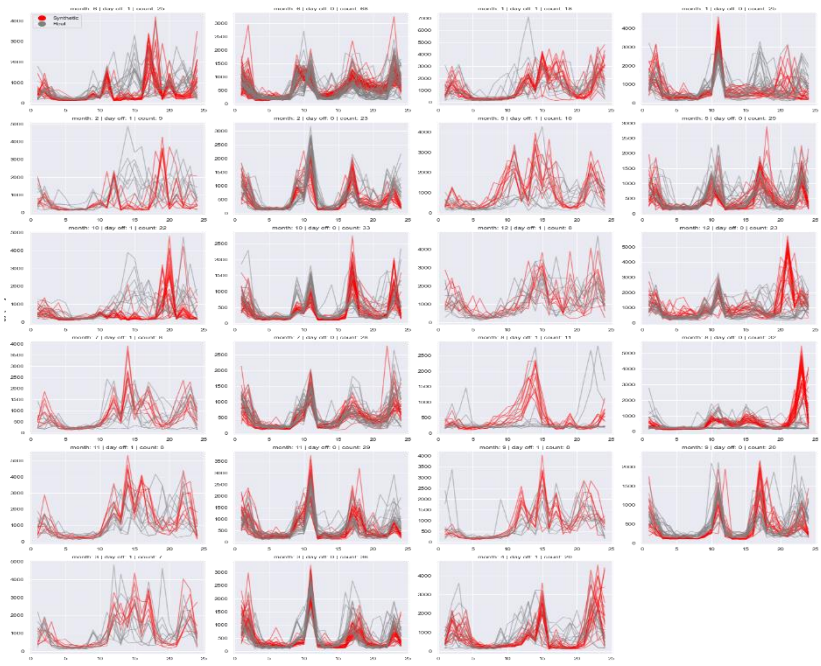

Figure 28: comparison between real and synthetic data

We have tried to extend the time window to a week, but the results were volatile and unsatisfactory. To address this limitation, we turned to Conditional GANs (cGANs), where both the generator and the discriminator are conditioned on auxiliary information (Pinceti et al., 2021). This approach allowed us to feed contextual information and enhance the model's ability to generate synthetic load profiles for more extended time periods, compensating for the challenges encountered with DoppelGANger. We aim to have a holistic methodology that captures the timeseries dependencies and generates synthetic load profiles across different time scaling.

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CONFERENCE TOPIC

Conference Topics this abstract refers: Digitalization for Future Energy Systems, IT technologies and Artificial Intelligence

BIOMASS TO BIOENERGY IN THE PROVINCE OF HUÍLA, ANGOLA

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SUMMARY

The search for cleaner energy sources in Angola has grown significantly due to the need to reduce the dependence on diesel generators to supply electricity, which, combined with the fossil fuels consumption in the transport and industrial sectors, puts the country on the path of those who have increased the greenhouse gas emissions over the last years. Only 30% of the population has access to electricity, despite the country's extensive resources of hydroelectric power and fossil fuels. Vegetable biomass accounts for 65% of the country's primary energy supply and 80% of the rural population depends on it to meet the majority of their energy needs. This biomass is burned in poor-quality devices, making them inefficient and causing health issues for the users exposed to the combustion gases. Therefore, this work aims to evaluate options for a greener and more sustainable use of the biomass to bioenergy. Different scenarios will be built based on the current use of the biomass to energy. Different burners will be considered that are more efficient and that provide better control of the emissions. Overall, the implementation of the different scenarios will be evaluated economically, socially and environmentally.
Recommendations will be delivered and policies that can contribute to energy sustainability in Angola will be identified.

INTRODUCTION

Africa is the third largest continent, with around 30,272,922 km^2, covering 20.3% of the planet's total dry land area (Amigun et al, 2008; UNFPA, 2011). Official data estimate that of the 8 billion inhabitants the world reached in 2023, 1.2 billion are in Africa, making it the second most populous continent (UNFPA, 2023). The population growth, with an annual doubling time of 28 years, is creating serious concerns as the predominance of young people in the population (43% of whom are under the age of 14) means that there is a need for major economic and social investment, particularly in the field of energy production, which will stimulate growth, guarantee stability and provide employment. The aim is to change the current situation by diversifying energy generation sources.

Studies carried out in 39 African countries have provided a better understanding of the continent's energy matrix, which is mostly based on mineral resources such as oil, coal and natural gas (Owen, Plas and Sepp, 2013). According to Mandelli et al (2014), in 2008, the African continent's reserves consisted of 130 billion m^3 of oil barrels, 14 trillion m^3 of natural gas and 31 billion tonnes of coal, distributed unevenly.

African countries contributed, in 2015, with 9.1% of the world's oil production, with Nigeria and Angola among the top 10 oil export countries (IEA, 2016). It should be noted that Africa has no country among the top exporters of oil-refined products. In this period, it only contributed with just 2.7% of worldwide oil-refined production and 5.8% of the 3,590 billion m^3 of natural gas produced worldwide, with Algeria and Nigeria among the top 10 world exporting countries. In terms of coal, African countries contributed with 3.5% of the total coal produced worldwide, where South Africa, is the only African country among the world's top 10 exporters of this energy source.

Despite the abundance of water resources of the continent, IEA (IEA, 2016) points out that, in 2014, no African country figured on the list of the top 10 hydroelectricity-producing countries. In addition, Africa has no countries exporting electricity and, in 2015, it generated only 3.2% of the 23,816 TW generated worldwide. Overall, there are 1,000 operational hydroelectric plants in Africa, of which 400 having an individual capacity of 10 MWh and 5 with a capacity of 1 GWh each (Mandelli et al, 2014). Regarding the amount of emissions, which is in the order of 32,381 Mt of CO_2 in 2015, Africa contributed with only 3.6%, thus reflecting its low energy consumption (IEA, 2016). According to the Africa Development Bank (2014), sub-Saharan Africa, with more than 800 million inhabitants, generates roughly the same amount of electricity as Spain, with 45 million inhabitants.

In Angola, only 5% of the hydroelectric potential is exploited, which represents a production of 5 TWh. All the 47 hydrographic basins in Angola have a generation potential of 30 to 35 TWh of electricity (Decreto Presidencial n.º 256/11). Angola produced around 9.48 TWh of electricity in 2014 and expects to increase it to 39.1 TWh by 2025 (Ministério da Energia e Águas, 2016), corresponding to an installed capacity of 9 GW (Decreto Presidencial n.º 256/11).

Biomass is the world's fourth largest energy resource (after oil, coal and natural gas), but its use is limited by its low energy density, the complexity of the supply chain (often in competition with food and materials) and high pollutant emissions (Bocci et al., 2014). As sub-Saharan Africa is considered the epicentre of the global challenge to overcome poverty, the use of biomass as a sustainable energy source could represent a breakthrough in improving global indicators. In most countries in the region, biomass is used as a subsistence fuel and is still considered a "traditional" source, with solar, hydro and wind being the renewable ones (Owen et al., 2013). This is why Malawi's energy policy planned to progressively reduce the contribution of biomass to the total primary energy consumption from 93% in 2000 to 50% in 2020 (Owen et al., 2013), but by 2023 it only had reached 70% (IRENA, 2023).

Bioenergy is obtained from biomass sources, such as dedicated crops, agricultural wastes, forestry and urban wastes. These sources are renewable and can be used sustainably, unlike fossil fuels, which are finite and contribute to increasing carbon dioxide emissions. By using bioenergy as a substitute for fossil fuels, it is possible to significantly reduce greenhouse gas emissions, as burning biomass only releases the carbon that was previously absorbed by plants during their growth, closing the cycle. Biofuel production can help diversify energy sources and reduce dependence on fossil fuels. However, it is important to ensure that bioenergy is produced sustainably, taking into account issues such as responsible land use, biodiversity protection and deforestation reduction.

To achieve this goal, this study aims to create scenarios on the sustainable use of the biomass to bioenergy in the province of Huíla, in Angola, by identifying domestic burners and community cookers with improved efficiency, that can be used for he production of heat. The available agroforest residues in the 52 communes of the 14 municipalities of Huíla province, was accounted, and the potential bioenergy production and the greenhose gas emissions saved were calculated for the different scenarios.
With Scenario 1, Business as Usual (BaU), only around 1.4 PJ of energy can be produced, with various associated environmental impacts. Improving the efficiency of the community cookers, improve the amount of energy produced and also the amount of greenhouse gas emissions saved. But, the change of the equipments has also an economical burden although, socially, the quality of life of the populations will be improved. The different scenarios are being evaluated in those three pillars of sustainability (economical, social and environmental), to provide recommendations and policies. Preliminary data shows that sustainable bioenergy production in this province of Huila in Angola is possible and represents an opportunity, but also poses several challenges, such as investment and social acceptance.

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CONFERENCE TOPIC

Solutions for Energy Efficiency

AGENT-BASED MODELLING OF POLICY INTERVENTIONS ON DISTRICT HEATING ADOPTION IN THE UK

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SUMMARY

An agent-based model has been developed to understand the dynamics and factors influencing the adoption of district heating (DH) solutions in the UK, particularly addressing economic, sociopolitical, and environmental considerations. The model facilitates testing of various policy interventions to understand their impact on DH expansion, aiming to offer practical insights for stakeholders and policymakers.

INTRODUCTION

In alignment with the 2016 Paris Agreement's Net-Zero 2050 goal, the UK grapples with heating and cooling, contributing to 50% of its energy consumption and 17% of national emissions (Frontier economics, 2021). Amid challenges like overreliance on natural gas and RET limitations (Gadenne et al., 2011; Inspired Energy, n.d.), District Heating (DH) emerges as a potential solution for urban regions, promising energy versatility, emission reductions, and cost savings (Energy Saving Trust, 2018). However, its large-scale adoption faces bottlenecks from investment, demand fulfillment and complex stakeholder interactions (Busch et al., 2014). While there is an increasing literature for low-carbon solutions and policy planning (Vuthi et al., 2022; Hall & Buckley, 2016), a knowledge gap exists in understanding how policy affects the dynamics of DH adoption growth (Webb, 2015). This study introduces an Agent-Based Model (ABM) as a pivotal tool to bridge this gap, offering insights into the complexities of policy and stakeholder interaction in DH expansion in the UK.

METHODOLOGY

Figure 1 is a flow diagram of the model overview, incorporating the model blocks as well as the inputs and outputs expected.

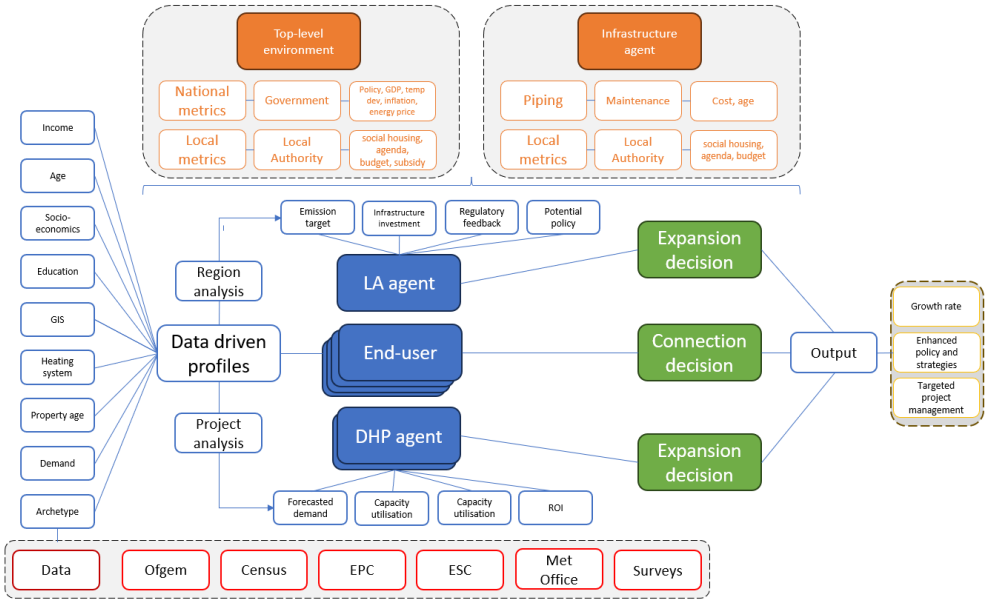

Fig. 1: Flow diagram of data-driven agent-based DH expansion model, including agent blocks, input data and outputs.

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Austria

This agent-based model explores DH adoption dynamics, focusing on economic, climatic, and sociopolitical influences and the decisions among key entities like DHP (District heat provider), households and commercial buildings, and local authoirties. The aim being to create data-driven profiles from open-source data, validated via heat pump adoption rates. These interactions take into account deviations in GDP and climate variations from an Enviroment Agent. Local Authoirty Agent makes decisions based on their political agenda and regions demographic, whereas the DHP Agent uses demand, and economics to strategise potential expansion. Households and Commercial Buildings Agents, meanwhile, factor in economic conditions, public perceptions, and various other determinants to decide on connections to the network.

The model, while not introducing policies, allows users to test different policy scenarios. It offers a practical tool for simulating real-world scenarios, and equips policymakers and stakeholders with a predictive platform to assess potential policy impacts, ensuring informed decisions that increase DH adoption.

PRELIMINARY RESULTS

Figure 2 showcases preliminary results from a simplified version of our model. Detailed insights will be discussed in the conference paper.

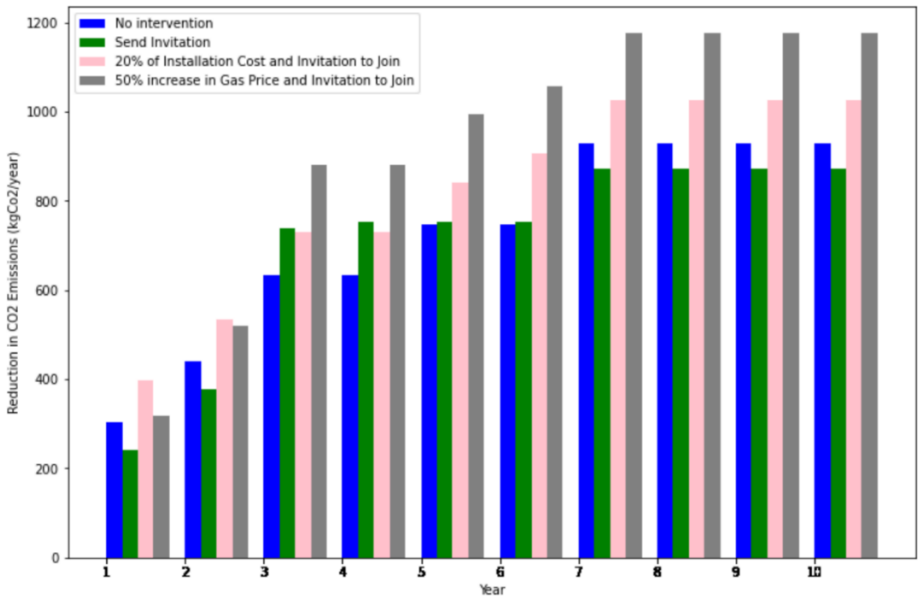

Fig. 2: Preliminary results of a simplified version of the model showing the reduction in CO_2 emissions when four different policies are introduced.

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CONFERENCE TOPIC

Future District Heating and Cooling Technologies, Policies, Spatial Energy Planning

IMPACT OF INSULATION DISTRIBUTION ON PERFORMANCE AND SPECIFIC COST OF LARGE-SCALE THERMAL ENERGY STORAGE

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SUMMARY

Large-scale thermal energy storage (TES) systems progressively emerge as key elements for future district heating (DH) systems. This is due to their capability to introduce and/or expand the renewable energy sources into DH system. Yet, a wide list of players restricts the practical application of TES systems in a cost-effective manner. In this work, a techno-economic analysis is carried out to reveal the impact of insulation distribution in large-scale TES. Therefore, six insulation configurations are considered in this work. The work shows improved energy efficiency for insulation distribution as truncated cone/pyramid compared to the full insulation distribution. Yet, this is associated with disimproved exergy efficiency. Moreover, the outcomes highlight moderate levelized cost of stored heat for such a distribution compared to the fully insulated one. However, the work considered variable insulation volume. Further steps will consider a constant insulation volume and conduct a further techno-economic analysis to comprehend the impact and gain further insights into the planning.
Keywords: Large-scale thermal energy storage, insulation distribution, underground tank, techno-economic analysis.

INTRODUCTION

One of the key measures to mitigate CO_2 emissions and to tackle the climate change challenge is the systematic transition from fossil fuels to renewable energy sources. Also, the development of more reliable and efficient energy systems is a milestone to expand the share of renewables in the energy scheme. Thus, large-scale seasonal thermal energy storage (STES) substantially facilitates a full exploitation of the local renewable energy sources (e.g. geothermal, solar, waste heat) potential (Yang et al. 2021). Large-scale STES bridges the gap between buildings' heating demand in winter and the availability of varying renewables resulting into an enhancement of flexibility in heat supply and demand.

LITERATURE REVIEW

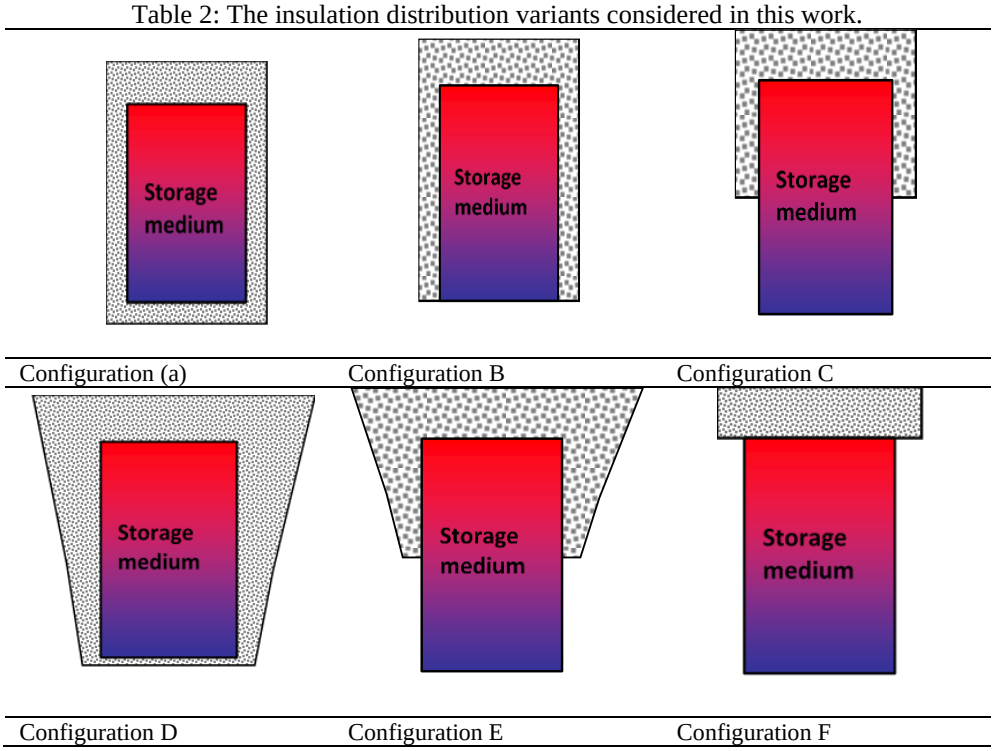
Hot water tanks and pits are costly to construct; therefore, TES must be properly planned prior to construction to ensure the economic feasibility and efficient operation. Accordingly, (Huang et al. 2020) discussed the impact of TES insulation level on the system operation. The work investigated 5 insulation levels (full insulation, no insulation, upper half insulation, lid insulation, lid and sidewalls insulation). The work showed an increase in the TES capacity if only the upper half of TES is insulated. (Kurşun 2018) assessed the stratification improvement under several insulation configurations. The work considered a residential hot water tank with a total volume of 33,6 L. The work suggested the use of an insulation in shape of truncated cone since it makes up to 131% stratification improvement compared to the conventional insulation installation. Yet, the TES scale is residential. This study examines the impact of insulation distribution within the STES envelope on technical and economic levels. To achieve this, a validated numerical model developed for large-scale, seasonal, underground TES systems will be used. The work will be focusing on large-scale hot-water tanks as potential candidates for DH systems. The investigation will focus on a volume of 100,000 m^3 as such volumes are seen for district level.

PRELIMINARY RESULTS

With the aid of numerical simulations, a fully buried tank with a total height of 50 m and a volume of 100,000 m^3 is investigated. The DH has supply and return temperatures of 90°C and 60°C, respectively. All insulation variants consider a top insulation thickness of 53 cm in order to produce U_{top} = 0.1 W/(m^2.K). Besides, the insulation material has a thermal conductivity of λ_{ins} = 0.08 W/(m.K). Moreover, Table 2 reports the different configurations for the insulation distribution considered in this investigation. As the fully insulated TES (configuration A) has relatively lower thermal losses, this means more heat can be discharged into the DH grid. Yet, configuration D arises as more promising insulation option as it reveals higher performance (i.e. energy efficiency and energy capacity efficiency) by 2.5% compared to its counterpart A as revealed in Figure 29. This is attributed to more insulation volume. Yet, the highest exergy efficiency goes for the configuration A as this indicates better stratification compared to all other options.

Figure 30(a) shows the specific cost for each configuration and it reveals that configuration D (gradient insulation over the sidewalls) possesses the highest specific cost due to the installation of insulation over the sidewalls and bottom resulting the largest insulation volume among all other configurations. Figure 30(b) depicts the levelized cost of stored heat (LCOS) for the several tank configurations in the foregoing discussion. Therein, it is revealed that the fully insulated tank has the highest LCOS despite its high efficiency (80%).

Table 2: The insulation distribution variants considered in this work.



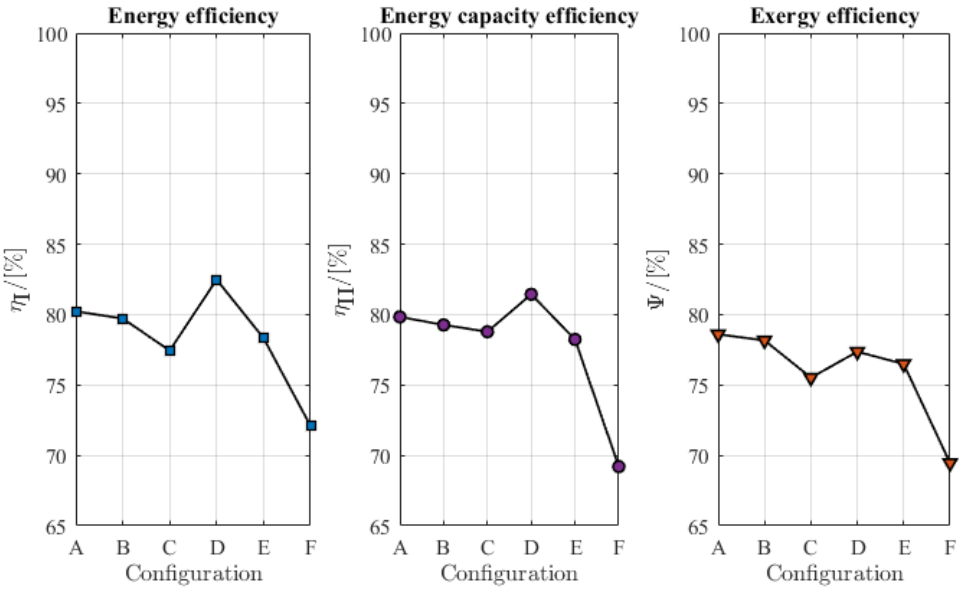
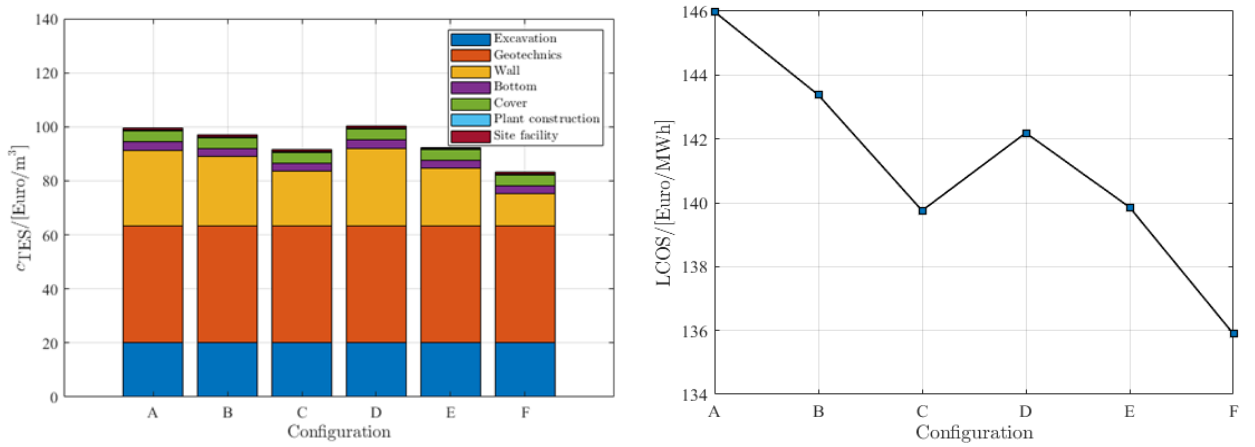


Figure 29: Energetic and exergetic efficiency for the different configurations considered for the insulation distribution for a 100,000 m^3 fully buried tank.



(a) Specific cost in (€/m^3) (b) Levelized cost of stored heat in (€/MWh)

Figure 30: Specific cost of large-scale TES (a) and levelized cost of stored heat (b)

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CONFERENCE TOPIC

This abstract refers to the conference topic: Emerging Heat and Cold Storages, Solutions for Energy Efficiency, Future District Heating and Cooling Technologies

FLEXIBILITY POTENTIAL IN THE AUSTRIA BUILDING SECTOR

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SUMMARY

What would happen if 15 % of the building stock in 2030 – both refurbished and newly-built – would use flexible heating/cooling systems to offer their flexibility on a market? How much annual residual loads from volatile RES could be absorbed? Our simple agent-market model says: ~10 % of RES surpluses and around 8 % of RES deficits. The cost of this operation is additional energy demand of about 20 %, indicating an efficiency of approx. 80 % in using these volatile supply peaks in flexible building operation. In this model, buildings are agents offering additional electricity consumption from pre-emptive HVAC operation, effectively using the building mass as storage. The offered flexibility thus depends on acceptable indoor temperature comfort bounds, the building mass and envelope and is modelled in a simple thermal RC model. The grid flexibility demand is derived from future residual load scenarios.
Key Words: Energy Flexibility, Building Stock, Demand-Side-Management, Residual Load, grid-supportive

INTRODUCTION

Austria's climate goals also call for a 100 % renewable energy supply by 2030. The significant expansion of (volatile) renewable energy sources necessitates increased dispatch flexibility: Despite an expected decrease in annual residual load until 2030, temporal residual load fluctuation are projected to remain similar to 2020 in magnitude and frequency (Esterl et al. 2022). According to Amann et al. (2021), approximately 39 % of the Austrian building stock (residential) needs to be renovated. To reach national and European climate goals, the renovation rate must increase rapidly and strongly by 2030 and 2040.

“Building as a battery” means converting electricity with heat-pumps and low-temperature heating/cooling systems such as thermal activated building systems (TABS) into an increase/decrease in building core temperature, storing the electricity thermally. The efficiency and cost-effectiveness of these systems is high, but subject to a number of constraints (Knotzer et al. 2019). Their operation is unidirectional, the thermal storage can only be charged actively but discharge is a passive operation, automatically happening over time. These charging/discharging speeds depend on building properties, differ between building types and determine the optimal frequency and duration of flexible operation: Highly efficient buildings can absorb and increase their demand for just a few hours before reaching comfort bounds, yet are able to maintain adequate temperatures for a longer period of time in comparison to less insulated buildings.

METHODOLOGY

The model consists of an hourly Flexibility Market and Agents of 36 buildings representing 36 typologies used to model the building sector. They are derived from building development scenarios in 2030 with moderate renovation rates of 1.8 in 2023 to 2.25 in 2030 (Amann et al. 2021) and new construction rate of 0.85 in 2023 to 0.58 in 2030 (Bürger et al. 2016). The building thermal models are single-zone RC models based derived from envelope, construction, and HVAC system properties, which lead to passive discharge durations from seventeen hours to well over four days assuming a maximum of 2 K overachievement of heating/cooling setpoint temperature after active charging.

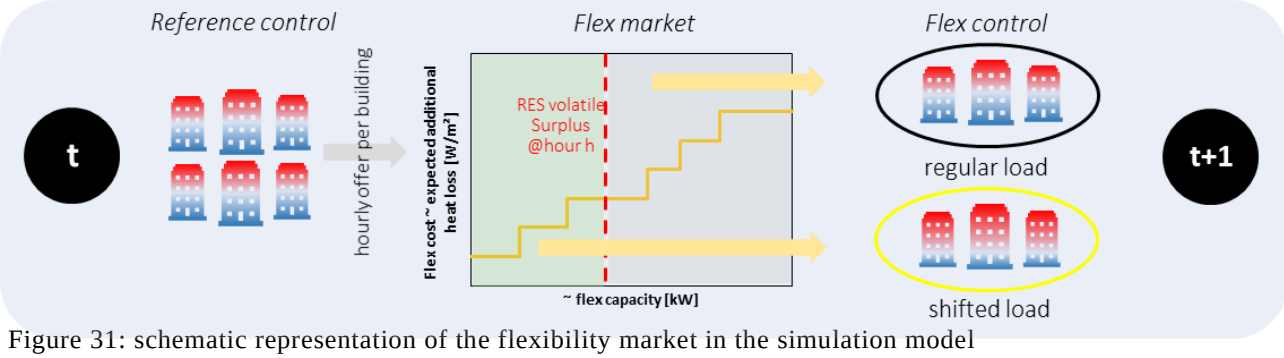

Figure 31: schematic representation of the flexibility market in the simulation model

In the market, flexibility capacity is offered each hour by building agents and cleared based on their estimated cost, which is defined as the expected additional heat loss: Better insulated buildings first.
After each timestep, the market clearing results in one of three states for each building: (A) active increase of energy demand, (P) passive decrease of energy demand due to discharge of the thermal storage, and (N) neutral operation, which means a load corresponding to the reference load profile.

RESULTS

With the methodology applied, the buildings from 2022 to 2030 can absorb 10.30 % or 9.6 GWh of surplus in the reference variant. 1.5 GWh are additionally required, 5 GWh can actively be shifted and 2.6 GWh can be shifted from times of systemic shortage to times of surplus. The variants (Min and Max thermal quality) of the building sector lead to deviations in the cleared Surplus of -0.33 to +0.60 %. The Min variant can manage the most active absorption of surplus (5.4 GWh active and 2.8 GWh passive), but at the same time requires 21.18 % (1.9 GWh) more energy than the reference variant.

Table 3: Results depending on sectors quality

KPIs	Reference	Minimum	Maximum	
Reference Heating&Cooling Demand w/o Flex	14.18	16.00	12.52	[GWh/a]
additional Demand	1.52	1.61	1.46	[GWh/a]
active Effect (A)	5.03	5.36	4.52	[GWh/a]
passive Effect (P)	2.62	2.82	2.38	[GWh/a]
cleared Surplus	10.30 %	10.90 %	9.97 %	[GWh/a]
Cost of Flexible Operation	0.199	0.197	0.212	[$Wh_{added}/Wh_{shifted}$]

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CONFERENCE TOPIC

Flexibility and Stability of Thermal and Electric Grids

MATERIAL INTEGRATION STUDY AND MODELLING OF A MGCL2: ALUMINA WATER-SORPTION THERMOCHEMICAL ENERGY STORAGE SYSTEM

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SUMMARY

Europe's changing energy landscape addresses climate change and rising electricity costs through thermal energy storage (TES). TES reduces emissions, integrates renewables, and enhances sustainability, but many technologies are in early development. Water-sorption thermochemical energy storage, particularly with $MgCl_2$-Al2O_3, stands out. System modelling with advanced control logic offers cost-effective optimization, potentially saving up to 30% of energy. This study characterizes a $MgCl_2$-Al_2O_3 composite for water-sorption TES, emphasizing its high heat storage capacity of 520 kJ/kg. The research aims to bridge the gap between material studies and real-world performance by investigating the potential of the composite in a fluidized bed reactor.
Key words: thermal energy storage, thermochemical energy storage, water-sorption, system modelling

INTRODUCTION

Europe's changing energy landscape addresses climate change and rising electricity costs, with thermal energy storage (TES) as a crucial solution following clean energy guidelines. TES reduces emissions, integrates renewables, and enhances sustainability, but many technologies are in early development, requiring cost-effective solutions. Sensible heat storage is simple but volume-intensive, latent heat storage faces material challenges, and thermochemical storage grapples with integration issues. Water-sorption thermochemical energy storage stands out for higher storage density. Choosing the right sorption material, considering factors like energy density and cost-effectiveness, is crucial.[1] Material conformation, like integrating sorption material into a porous matrix, is key. This study focuses on $MgCl_2$-Al_2O_3 as a promising water-sorption material for a flow reactor.[2]
System modelling in water-sorption thermochemical energy storage, especially when paired with advanced control logic using Modelica, offers a cost-effective way to optimize energy systems and enhance efficiency. These models provide valuable insights for Europe's sustainable energy goals. Advanced control logic, crucial in thermal systems, could potentially save up to 30% of energy. In this study, an integrated water-sorption system is modelled to assess time-dependent TES capacity, with a key challenge being accurate tracking of the sorption/desorption process for innovative materials lacking published isotherm data.

METHODOLOGY AND RESULTS

A composite Al_2O_3-$MgCl_2$ was prepared by combining a saturated solution of 125g of $MgCl_2 \cdot 6H_2O$ with 100g of Al_2O_3 at room temperature, followed by drying at 130 °C for 2 hours. Thermochemical energy storage and thermal properties were characterized between 25 and 130 °C using various techniques, including DSC for heat capacity, DSC-TGA for desorption processes, and hot disk for thermal conductivity analysis. Charge/discharge cycles were conducted in a controlled temperature and humidity chamber. SEM-EDS was used to examine particle size, appearance, and composition of the composite.

Table 1: water-sorption TES properties of $MgCl_2$-Al_2O_3 (average for different charge/discharge conditions).

Dehydration Reaction	Charge (°C, RH%)	Discharge (°C, RH%)	TES capacity (kJ/kg)	Thermal Conductivity (W/mK)	Heat Capacity (kJ/(kgK))
$MgCl_2$*$6H_2O$ to $MgCl_2$*$4H_2O$	55-69, 80%	75-116, 0%	520	0.160	2.25

Regarding the modelling of the sorption system, it consists of the open sorber, control logic and the sorbent medium. In this work, and for the sorbent material modelling, a sorption model proposed by Dubinin[3] was adopted. The model assumes pore filling to be induced by an "sorption field" in the micropore space set up by the solid body. This filled pore volume, as Dubinin has concluded, is only a function of the sorption potential, which can be interpreted thermodynamically as "Gibss free energy". On the other hand, the open sorber model consists of a group of submodules (a model of sorbent cell, mass transfer diffusion, and heat exchanger), connectors for dry steam and humid air are used to connect the sorber to the system boundary conditions, and hence the control logic. The modelling part was executed using the object-oriented language Modelica. Preliminary results are shown in Figure 1. The first "blue" profile demonstrates the heat flow exothermic (-ve) for about 750 seconds. This heat flow is released by allowing a flow of humid air at 30˚C "blue second profile" and 90 % to 33% RH "green and red third profiles" of sorber air entering and leaving RH values. The process concludes with the charge, by using super-heated steam flow with a temperature of 130 ˚C. The endothermic heat flow (+ve) reaches 200kW and lasts for 200 seconds.

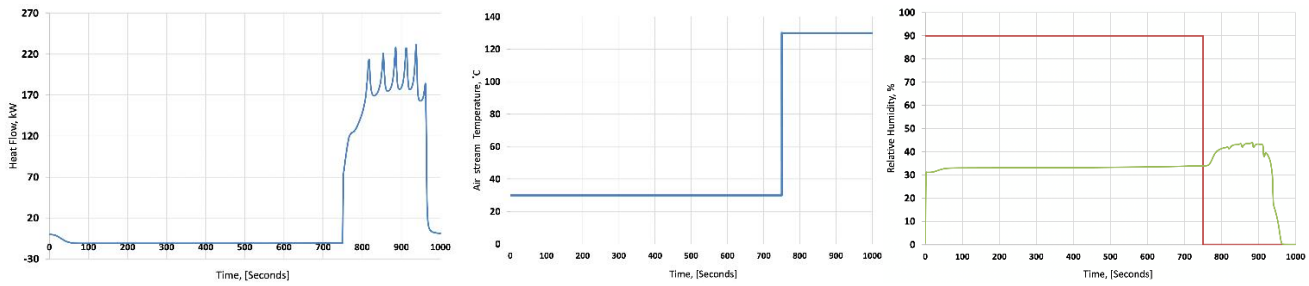

Fig. 1: Heat flow (left), Air Stream Temperature (middle) and input (red) and output (green) relative humidity versus time.

CONCLUSIONS

This study focuses on characterizing the Al_2O_3:$MgCl_2$ composite for water-sorption thermochemical energy storage. Previously explored for ammonia-sorption, this composite offers advantages over zeolite, a costlier material. It exhibits a high heat storage capacity of 520 kJ/kg. Nevertheless, the modelling package investigates the dynamic performance of desorption/adsorption processes under different boundary conditions. Hence, it will provide insight into the design and operation phases. The research aims to bridge the gap between material studies and real-world performance by investigating the composite in a fluidized bed reactor, addressing this crucial aspect of its application.

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CONFERENCE TOPIC

Emerging heat and cold storage.

HIGH TEMPERATURE INDUSTRIAL HEAT: COLLECTOR AND STORAGE DEVELOPMENTS AND OUTLOOK

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SOLAR INDUSTRIAL HEAT SURVEYS

Solrico carries out surveys among global turnkey SHIP suppliers on an annual basis since 2016 to identify market trends and the global SHIP market of the previous year [1]. Since Feb/March 2023 the survey included also questions regarding SHIP projects in the planning phase and under construction. Based on a database of more than 60 projects for which commissioning is planned to take place between 2023 and 2026 the first Solar Industrial Heat Outlook was launched in September 2023 [2]. This outlook illustrates a clear trend towards an increasing number of high temperature solar industrial heat projects to be commissioned globally (outside China) in the coming years. The next SHIP turnkey supplier survey is planned to be carried out in the first quarter of 2024 and will update again the project database for the Solar Industrial Heat Outlook. During the ISEC 2024 brand new market information will be available based on this new survey.

TRENDS AND MOOD AMONG TURNKEY SHIP SOLUTION PROVIDERS

The number of providers with higher temperature solar process heat solutions continues to grow. More manufacturers of concentrating collectors are now listed on the SHIP Supplier World Map [3] than manufacturers of stationary collectors. During the presentation at ISEC newcomers with high-temperature solutions among the registered companies on the SHIP Supplier World map will be introduced. Also the general mood on the SHIP market depending on the world region will be analysed.

HIGH TEMPERATURE STORAGE SOLUTIONS

SHIP plants that deliver more than 100 °C also need storage volumes, The industry of high temperature storage solutions is growing dynamically, but was never assessed systematically. Solrico plans to carry out an industry assessment among high temperature storage solution providers in Europe and North America. The idea is to identify storage tank concepts, typical heat transfer media, possible demo projects etc. During the presentation at ISEC the results of this market assessment will be presented for the first time publicly.

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ENHANCING FAULT DETECTION IN DISTRICT HEATING SYSTEMS: A MACHINE LEARNING APPROACH USING SIMULATED DATA FROM AN AUSTRIAN NETWORK

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SUMMARY

This study underscores the importance of timely fault identification in district heating systems. The challenge lies in adapting fault detection methods to the diverse configurations of district heating networks. The study establishes a physical model to emulate faults, generating simulated data for machine learning algorithms applied to a district heating network in Austria. Visualization through Grafana enhances fault diagnosis. Despite challenges like limited labeled datasets, the research contributes valuable insights for the fault detection and diagnosis application of the district heating networks.
Keywords: *Dynamic simulation, district heating network, energy services, fault detection and diagnoses*

INTRODUCTION

The timely identification and accurate diagnosis of faults within the district heating are crucial for maintaining optimal performance, preventing potential disruptions, and maximizing energy efficiency. By addressing issues promptly through effective fault detection and diagnosis (FDD), operators can enhance the overall resilience and sustainability of district heating and cooling infrastructures and reduced environmental impact. Recent investigations reveal that a considerable percentage of examined substations demonstrate suboptimal functioning due to faults. This results in elevated return temperatures, negatively impacting customer comfort, heat retention, hydraulic capacity, and production efficiency [1].

District heating networks often exhibit diverse configurations due to differences in geographical layouts, (building structures, and fluctuations in heat demand due to changes in weather) and scale. Some faults (pipe blockage, leakage) may manifest differently in different network configurations. Developing generic fault detection methods that can be adapted to these variations is a significant challenge.

Achieving real-time fault detection and diagnosis is critical to minimizing downtime and preventing cascading failures. However, implementing real-time algorithms that can handle the complexity of district heating networks adds an additional layer of difficulty.

Considering these challenges, manual FDD methods prove to be time-consuming, expensive, and susceptible to errors especially as the scale of the network increases. Hence, the automatic fault handling becomes paramount to maintain an optimal network and mitigate the impact of faults. On the other hand, the data monitored by the network operators is focused on standard parameters respectively to the information related to billing rather than giving precedence to FDD. Assessing whether the currently available data is suitable for automated FDD becomes essential, along with identifying the specific supplementary information required to enhance FDD accuracy. The absence of comprehensive, high-quality labeled datasets specific to district heating networks hinders the development and testing of accurate models [1]. Additional to the lack of high-quality labelled data on FDD, district heating networks are inherently complex systems with intricate dynamics. Understanding and modeling the behavior of these networks under various operating conditions and potential faults is a challenging task [2].

In this research, a physical model of the district heating network is established. This model is employed to emulate faults such as sensor failures and pipe issues in various network segments. The simulated data generated from these fault scenarios is then utilized to develop generic machine learning FDD algorithms. Different machine

learning models are compared based on the accuracy, geographical layout of the network. The alarm system is visualized in Grafana, an open-source analytics and monitoring platform that integrates with various data sources.

METHODS

The modeling and diagnostic approaches developed in this study are applied to an existing district heating network Austria.

Language and Tools

For the physical modelling, the network topology is defined in Python environment, this representation is automatically translated into Modelica environment for the simulation in software Dymola [3]. Modelica is a standardized, acausal, equation-based modelling language used to model and simulate complex multidomain physical systems [4]. The study of comparison of general-purpose tools and modelling paradigms for district-scale energy systems highlights that Modelica is a promising modelling language for DHC systems simulations since there are many open source and commercial libraries available containing components for DHC. For the FDD algorithms, Python environment is used.

Network Simulation and Assessment

The modeling and diagnostic approaches developed in this study are applied to the district heating network located in Stanz, Austria with 630 m route length and 11 consumers which comprise single family houses. The topology of the network is represented in Figure 1. Figure on the right-hand side shows all the consumers in circles corresponding the nominal load. The maximum nominal load belongs to the C5 with 114 kW; minimum load belongs to C4 and C9 with 11 kW.

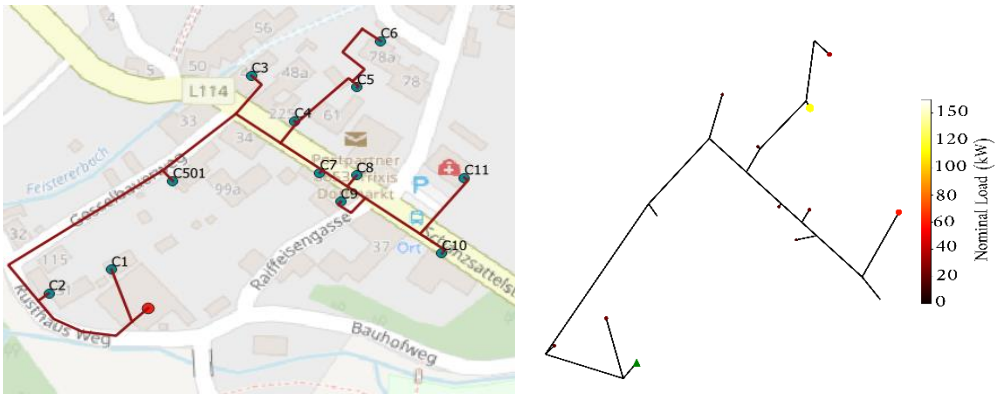

Figure 32: On the left-hand side: Topology of the network. On the right-hand side: Distribution of the nominal load of each consumer in Python layout.

Figure 1 on the right-hand side shows all the consumers in circles corresponding the nominal load. The total nominal load is 9.5 MW. The minimum annual total load is 16.5 kW.

Deployment of the FDD

Within the simulation of the network, the emulations of leakage and fouling faults are incorporated. FDD are facilitated through the application of clustering and regression algorithms by using the simulated data. These algorithms are deployed to identify faults simulated across various sections of the network topology and different sessions, with a subsequent comparison based on the diagnostic accuracy of FDD models.

This study will present the workflow of generic fault detection and diagnoses in the network, visualize faults within a dashboard, and explore the energy-saving potential within the network.

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CONFERENCE TOPIC

Digitalization for Future Energy Systems

UNIFORM MODELING OF HEAT PRODUCTION COSTS IN SINGLE-FAMILY AND MULTI-FAMILY HOUSES

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SUMMARY

To ensure a fair and extensive comparison of different heating systems four representative buildings including their heat demand for space heating and domestic hot water were defined. A model for the heat production costs has been developed based on existing methods like the VDI 2067 part 1 [1] and the simplified approach for the calculation of the "Levelised Cost of Heat" (LCoH) of the IEA SHC Task 54 "Price Cost reduction in solar thermal systems". The developed model includes the costs of purchase, installation, operation, maintenance and disposal and was implemented in an EXCEL calculation tool which enables the calculation of the total life cycle costs (LCC), the levelized cost of heat (LCoH) and the CO_2 emissions over the lifetime of the system.
Keywords: Life cycle costs (LCC), levelized cost of heat (LCoH), heat production costs, heat demand

INTRODUCTION

The provision of heat for residential buildings has a significant impact on the sustainability of the energy supply and represents an immense cost factor. To optimize the heat supply regarding the current climate policy objectives, various technologies and their combinations are available, which focus in particular on the use of renewable energy sources. But especially for the use of renewable energies, which must cover 65% of the heat supply of residential buildings in Germany from 2024, the requirements of planners, decision-makers and users as well as the overall socially responsible parties are very high with regard to the sustainability of the systems used and the costs. Due to insufficient knowledge and development of the existing methods for life cycle and cost analysis as well as the lack of models and data for this purpose, these cannot currently be assessed in a comparable manner.

For the ecological and economic evaluation of systems and components for heat supply in residential buildings, a multitude of influencing factors over the life cycle play a role. The project "Efficient Heating", initiated by Fraunhofer ISE, Fraunhofer IBP and the Institute for Building Energetics, Thermal Engineering and Energy Storage (IGTE) at the University of Stuttgart and carried out jointly with representatives of the heating, real estate and planning industries, aims to understand the underlying complex interrelationships between the different factors. On international level the IEA SHC Task 71 “Life Cycle and Cost Assessment for Heating and Cooling Technologies” aims to harmonise methods for the life cycle and cost assessment for heating and cooling technologies.

The reliability of the data regarding the basic materials used, manufacturing techniques, installation, maintenance and end of life is to be supported by data collection directly from the industry, among others. In addition to the exemplary comparison of alternative materials, components and manufacturing processes, the influence of a variable lifetime energy yield shall be considered. The investigations are to be carried out at the level of building integration and, for selected questions, also in the economic context. To improve data availability and decision support, the environmental and cost information generated in the project will be made available to potential users to enable them to select ecologically and economically advantageous variants.

FIRST RESULTS

For the comparison of different heating technologies well defined heat demands are required. To fulfil this requirement and cover a large share of the residential market in Germany four buildings including the corresponding heat demand for space heating and domestic hot water preparation were defined:

- Single family house (stock)
- Single family house (new building)
- Multi-family house (stock)
- Multi-family house (new building)

For the different load of the four buildings generic heating systems will be defined which cover the different loads. These heating systems are simulated in the simulation environment Polysun. The results of the simulation as gas and electricity consumption are input into the cost calculation.

A uniform modelling of the heat production costs in single and multi-family houses has been developed based on existing methods like the VDI 2067 part 1 [1] and the simplified approach for the calculation of the "Levelised Cost of Heat" (LCoH) of the IEA SHC Task 54 "Price Cost reduction in solar thermal systems" [2]. The model includes all costs arising from the purchasing and installing the system, operating the system, maintaining the system up to the disposal of the system. The extensively parameterizable model of life cycle costs and heat production costs was implemented in an EXCEL calculation tool and can be applied to all available heating systems to ensure a fair comparison of the different technologies and, if necessary, their combinations. The costs of purchase, installation, operation, maintenance and disposal are included. In addition, parameters such as subsidies, CO_2 taxes, etc. are included to enable an economic approach to economically advantageous variants.

The full paper will present the four defined buildings, a detailed description of the cost calculation model and its parameters as well as first cost assessments of different heating technologies.

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ACKNOWLEDGEMENTS

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CONFERENCE TOPIC

Renewable heating and cooling

DECARBONISATION OF PUBLIC VEHICLE FLEET AND ITS IMPACT ON SECTOR COUPLING

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SUMMARY

The mobility sector stands for about 30% of the final energy demand in the EU27 (Eurostat, 2023). Current strategies to achieve set decarbonisation or defossilisation goals by 2030 are mainly based on e- and H_2-mobility, both strongly depending on the local or regional availability of green relectricity. At the same time local authorities are encouraged to identify solutions to convert fossil fuel-based vehicle fleet (busses, garbage trucks, snow removal vehicles, etc.) to alternative drive technologies[6]. The gap in this process can be identified between the available e- or H_2-based vehicles and the therefore necessary energy generation and supply infrastructure to provide electricity locally and limit the dependencies on supply grids and its expansion. Beside the mobility sector also industry and households must be decarbonised, all of them depending on local availability of renewable energy carriers and technologies. This paper focusses on the developed methodology to define the necessary infrastructure including all available renewable technologies offering a potential for green electricity as well as the necessary sector coupling between heat and electricity.

INTRODUCTION

Local authorities operate communal road vehicles or assign corresponding services to fulfil their statutory and voluntarily assumed services. Many cities and municipalities are already endeavouring to convert their vehicle fleets to alternative drive technologies. In addition, the Clean Vehicles Directive of the EU27[7] defines the achievement of minimum share in the procurement of clean communal vehicles. However, the challenges in this field are given, mainly when a municipality must choose suitable vehicles for public transport, garbage disposal or snow removal. The purchase of a clean vehicle is a crucial decision with a high impact on the need for investment in the accompanying charging and refuelling infrastructure and even more importantly in the necessary supply technologies. The available vehicles are still under development to match the required capacity and power of fossil fuel-based ones. The core technologies are mainly e- and H_2-mobility, both causing a significantly higher electricity demand in the future. The mobility sector accounts for about 30% of the final energy demand in the EU27 (Eurostat, 2023) and is competing with the industrial and household sector when it comes to the use of locally or regionally available renewable energy carriers and technologies. This must be taken into consideration in the decision process of switching an existing vehicle fleet to renewable energy.

METHODOLOGY

The project KOFIX addresses the mentioned challenges in the decision and investment process based on the showcase municipality of Leoben, Austria. The objective is to evaluate the energy consumption of the fleet in different states (e.g. winter, summer) and of different vehicles to determine the crucial parameters influencing the energy demand finally, to develop a methodology to predict the renewable energy requirements of the fleet

[6] Mobilitätsmasterplan 2030 für Österreich https://www.bmk.gv.at/dam/jcr:6318aa6f-f02b-4eb0-9eb9-1ffabf369432/BMK_Mobilitaetsmasterplan2030_DE_UA.pdf

[7] https://transport.ec.europa.eu/transport-themes/clean-transport/clean-and-energy-efficient-vehicles/clean-vehicles-directive_en

which is transferable to other municipalities. To this end, a combination of operational, vehicle and environmental data is analysed to create energy profiles for different vehicle classes, in order to identify the crucial parameters that influence specific energy demands. The most obvious ones are the purpose of the vehicle and the varying of weight of the vehicle, the relevant topography, the experience of the driver, but also necessary unloading and refuelling periods. But also the season, the interlinked client (household) demands and behaviour has to be considered within this long list of influencing parameters.

These load profiles will be different when a fossil-fuel based vehicle is substituted by e- or H2-mobility solutions. The main reasons are the changed capacities, the weights but also the higher efficiencies of these vehicles. Different scenarios of load profiles (equal to existing ones, partly and total share of renewables in supply system) are evaluated as a basis for the definition of the increased energy demand. The calculated demand profiles are matched with local and regional available renewable energy sources. These include photovoltaics, hydrogen power, wind power, biomass and biogas that can be applied to cover the electricity demand of the future municipality fleet (see Figure 1). Depending on the fluctuations of the demand but also on the volatility of the supply technologies, it is evident that sector coupling must be considered in this process:

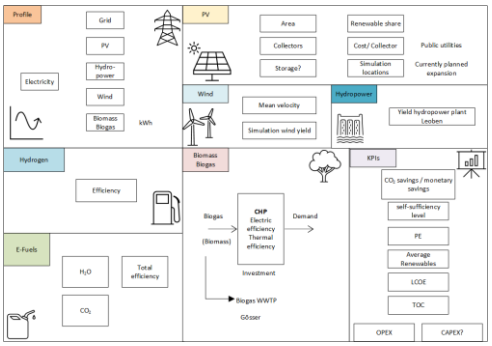

Figure 33: Evaluation of renewable energy carriers and technologies to provide green electricity to the local vehicle fleet

- Collaborative use of supply technologies
- Link generated electricity and heat (e.g. biomass, biogas) to all relevant sectors including households and industry
- Identify all sources for technologies as biomass or biogas being collected again from all sectors

The parameters on which system design and finally investment decisions will be based on economic but also ecologic ones, both requested in the European Green Deal[8] and the interlinked taxonomy[9] strategy including CO_2-savings, grade of autarky, primary and final energy demand, levelized costs of energy, necessary investment, etc.

OUTLOOK

A municipality does not have the knowledge to make a reasoned choice towards a sustainable vehicle fleet in the future and how to be in line with the clean vehicle directive, nor can it evaluate whether the supply from the existing electricity grid is sufficient for its needs and will therefore not take care of the increasing electricity demand and its coverage. Then as mentioned before also other sectors will consume more electricity in the process of decarbonisation and mobility is of high relevance for households and industry (logistics and employees). Therefore, the approach of KOFIX is to initiate a sector-coupling process and develop a transferrable methodology to actively include municipalities in the green energy future.

ACKNOWLEDGEMENT

This paper is based on the work of the project KOFIX – Kommunaler Flottenmix, (project number 891460) funded by the Federal Ministry for Climate Action, Environment, Energy, Moility, Innovation and Technology, Republic of Austria within the call “Mobilität der Zukunft, 17. Ausschreibung 2021”. The project is coordinated by TRIAGONAL GmbH with the partners eCustodia GmbH, Municipality Leoben and University of Applied Science, FH JOANNEUM Gesellschaft mbH

CONFERENCE TOPIC

[8] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[9] https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

This paper addresses the conference topic(s): Coupling of energy sectors and policies

A REVIEW ON POSSIBILITIES AND CHALLENGES OF PIT STORAGES IN SWEDISH SOLAR DISTRICT HEATING NETWORKS

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SUMMARY

The construction of pit storages enables higher solar fraction in the district heating networks while counteracting the mismatch between heat demand and production in solar district heating (SDH) installations. Capital cost is the deciding factor for pit storage constructions and is directly linked to site specific geological conditions. This study investigates social and technical conditions for the implementation of pit thermal energy storages in Swedish district heating networks. With Denmark having several successful SDH and pit storage installations in operation, the country is used as reference in comparing the socio-techno economical differences between the two countries. This study, which is based on literature review, suggests significant difference in social conditions between the two countries, with Denmark having had the necessity to develop technologies for heat production due to insufficient waste and biomass incineration in comparison to Sweden.

INTRODUCTION

Solar thermal heat production in industries and solar district heating (SDH) networks enhance reduction of greenhouse gas emissions, contribute to fuel flexibility and reduce dependency on fuel prices (1). Currently, thermal energy constituting half of the total energy use in the world and is therefore regarded as an important target for CO_2 reduction and energy efficient measures. According to IEA Net Zero Emissions Outlook, solar thermal (ST) could constitute up to 35% of total hot water production by 2050. An increased use of ST in the energy mix also contributes to Sweden's 2045 climate goals (2).

With heat storages assisting in counteracting the mismatch between heat production and heat demand in SDH systems, such installations in the northern hemisphere may be viable despite low solar energy intensities and limited solar energy during winter season (3). Sweden has yet to adopt the concepts of SDH and thermal storage, despite ongoing debates regarding decarbonization of the heat sector (4). Denmark on the other hand has several pit storages in operation, and accordingly, there could be some learning possibilities for Sweden from Danish experiences.

METHOD

The aim of the study is to explore Swedish social and technical conditions regarding implementation of pit storages and SDH, using Denmark's experiences. Literature studies were mainly delimited to Danish case studies on operational pit storages and SDH installations and studies involving geological conditions in Sweden.

RESULT

The preliminary findings show a distinctive difference in social factors between the two countries. In the case of SDH installations in combination with pit storages, Sweden has a long well-established history of waste incineration and district heating facilities that use biomass as the main fuel. Accordingly, there is a strong path dependency towards these technologies. Further, in Swedish context biomass as a fuel is regarded as carbon

neutral. These along with mismatch between solar energy availability and the heating demand may be limiting the diffusion of SDHs in Sweden. However, Bryngemark (5) and Jordan et al. (6) concluded that bioenergy will be a resource facing competition in the future with increasing demand due to carbon neutrality targets. Their analysis showed increased price of biomass due to raw material competition from different industries such as the construction industry. The higher feedstock prices may make the use of forest biomass in the district heating sector less profitable. Mathiesen et al (7) showed that integrating large-scale solar thermal in DHS would be one way to reduce the demand for biomass. In Sweden, district heating companies regard heat storages in combination with SDH a necessity for feasibility and utility. In addition to increasing solar fraction of SDH installations, benefits such as security of supply, load fluctuation resilience and dynamic electricity production follow the construction of heat storage implementations (8).

While the construction of pit storages may be possible in most ground conditions, the deciding factor for district heating companies is the capital cost directly linked to site-specific geological conditions that varies greatly throughout Sweden. With less potential heat losses and lower capital cost, pit storages should be constructed in the proximity of the collector field, further delimiting the possibilities for placement.

CONCLUSION

The study highlights both technical and social challenges for the implementation pit storages in Sweden, where the biggest challenges are social factors connected to strong competition for SDH with other well-established heat production technologies.

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CONFERENCE TOPICS

Renewable heating and cooling, including high temperature applications; Enmerging heat and cold storage

BUSINESS MODELS FOR CIRCULAR BUILDING PRODUCTS

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SITUATION

The globally limited availability of primary resources makes Re-Use in construction necessary and sensible. Re-use of resources like building products and components protects ecosystems in primary resource extraction areas, increases the resilience of the economy and enables sustainable business, while at the same time not wasting land for landfills.

While before 1900 Re-Use in construction was the rule and not the exception, Re-Use is now not common any more in Europe, Re-Use business models in construction have vanished, and recent developments in construction methods (e.g. use of adhesives) are reducing the ability of buildings to be decomposed without destroying components.

With circularity a main topic in sustainable development, there are now efforts to re-introduce Re-Use in the construction sector (European Circular Economy Action Plan 2020[10], revision of Construction Products Regulation[11], integration in harmonized European Standards etc.). In practice Re-Use is however mostly limited now to non-critical components like floor coverings and furniture. Re-use of building components such as beams, windows, suspended ceilings - although often technically possible - still takes place very rarely, and is limited to demonstration projects, like the ones supported by research projects ReCreate[12] (concrete) and DISRUPT[13](steel).

GOAL

In this work we focus on Business Models that enable or simplify Re-Use of building components and products and show how they are allocated to the building development process in circular economy. The goal is to show how buildings can use Re-Use components and/or can be completely dismantled at the end of their life.

METHODS

The Business Models are collected, developed and characterized with focus on three specific Use Cases of buildings with short usage periods, namely supermarket, office building and interim building, where the implementation of Re-Use has a particularly strong impact on resource balance. The visualization allows for a fast assessment and analysis of the business models. Moreover, business models for building products are allocated to a Building Development Process Model which considers Re-Use, as shown in Figure 34.

CONCLUSIONS

The analysis of the Use Cases and discussions with stakeholders showed that the re-useability of building components can be considerably increased by applying construction methods that allow for decomposition. However, for Re-Use to become feasible and attractive for professional building owners and developers, reliable and attractive Re-Use products and Business Models are needed. Some product developers have already reacted

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:98:FIN
[11] https://ec.europa.eu/commission/presscorner/detail/de/qanda_22_2121
[12] https://recreate-project.eu/
[1313] DISRUPT Steel Reuse Project – Toolkit - The Alliance for Sustainable Building Products (asbp.org.uk)

to this need and offer such products. The main advantage of true Re-Use business models is that they offer an answer to open questions on warranty and liability, which usually arise at second use.
Re-Use Business Models for Building Products may offer a closed cycle already at the moment when the product is first adopted, or like a Re-Use platform offer a framework to enable Re-Use. Re-Use Business Models include:

- Loop Products: The product is taken back and sold like any other product after refurbishment
- Re-Useable Construction System: the producer offers dismantling, testing, buy back and warranty also for repeated use
- Re-Use retailers: buy and sell Re-Use Products, organize tests and offer a warranty for a variety of products
- Re-Use platform: possibility to sell and buy Re-Use products, with added value like tests, guarantee and product information services

The analysis gives an overview on the main advantages of the Business models, shows which challenges persist and gives examples of companies and organizations that offer such businesses.

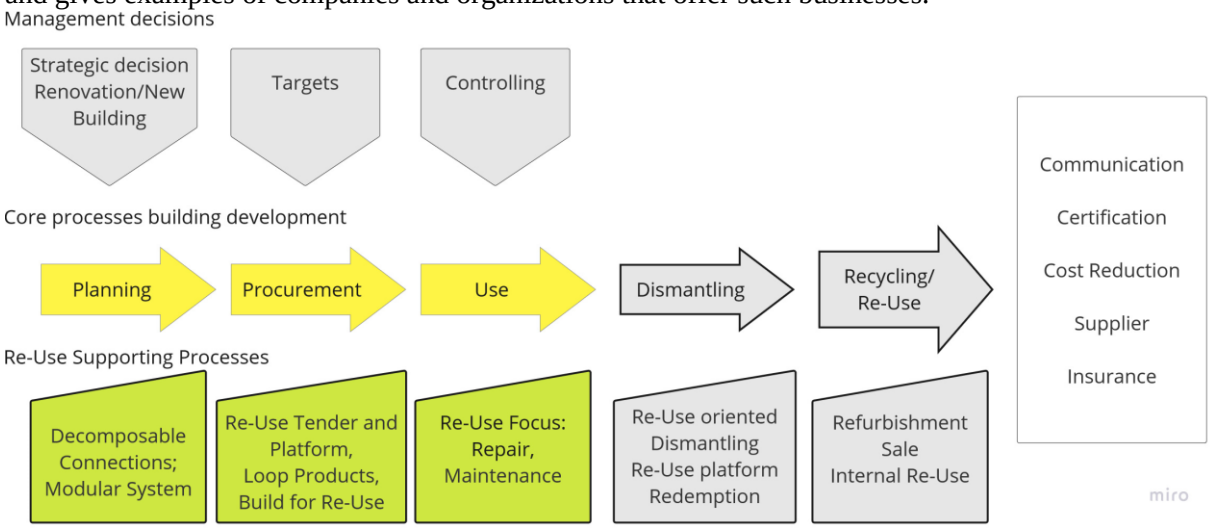

Figure 34: The Process Diagram for Circular Construction. shows that circular building development does not primarily concern the dismantling and disposal phase of buildings, but rather starts in the planning and construction phase. Moreover, circularity has to be considered along the whole decision taking levels. Re-Use and Circularity specific goals should be part of the main targets, just like other sustainability targets, be part of the business culture and the Controlling.

LINKING THE DEVELOPMENT OF RENEWABLE ENERGY PROJECTS AT MUNICIPAL LEVEL WITH NECP PLANNING AND REPORTING

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SUMMARY

Regarding the National Energy and Climate Plan (NECP) according to EU Governance Regulation, there is a disconnect between the federal and municipal levels that hinders effective planning and reporting, especially in the area of renewable energy sources (RES) where availability depends on the regional spatial conditions. The project transFORMAT-LINK addresses this challenge based on case studies and stakeholder discussions. Results are (1) the LINK Guideline for municipal development concepts/plans to support RES project implementation and to simplify NECP planning and reporting; (2) the LINK software prototype for developing and monitoring municipal development concepts/plans according to LINK Guideline. This contribution presents results, focussing on minimum requirements for municipal development concepts/plans under the regional spatial planning laws and how they will facilitate the implementation of renewable energy projects.
Key words: Renewable energy, spatial planning, sustainable cities, municipality development

INTRODUCTION

The National Energy and Climate Plan (NECP) is the key policy instrument to ensure that the objectives of the five dimensions of the Energy Union are achieved by 2030, with a view to long-term improvements by 2050. The European Climate Law sets ambitious targets for the reduction of greenhouse gas emissions and thus emphasises the essential role of renewable energy. The importance of renewable energy sources for achieving the energy and climate targets also emphasises the spatial dependence of the availability of renewable energy sources and the associated challenges posed by the division of tasks within Austria. The usability of renewable energy sources is area-dependent and is therefore subject to spatial planning. Looking at the Federal Constitutional Act, which defines the division of competences between the federal government and the provinces, it becomes clear that there is no direct legal responsibility for spatial planning at federal level: Article 118 (3) states that the municipality has competence within its own sphere of action for the management of certain matters listed in the Act, including local spatial planning. Looking at the Austrian NECP 2019, spatial planning was mentioned as a very important instrument, but no specific measures were described. The central question was how the existing situation can be improved in terms of a better link between the federal NECP plan and local spatial planning, especially with the aim of facilitating the development of renewable energy projects.

THE TRANSFORMAT-LINK PROJECT

The challenge described above is addressed by the transFORMAT-LINK project, funded by the ACRP Program (14th call for proposals) with the duration from 01.10.2022 to 30.09.2024. The consortium consisting of SERA global GmbH, TU Wien and Kleboth und Dollnig ZT GmbH has been working on developing the following results: (1) Harmonised minimum requirements for local development concepts or plans in terms of elaboration, criteria for content, documentation and accessibility. (2) Standardised criteria to reduce the risk of conflict: when defining the criteria for the content to be covered, possible conflicts of objectives are taken into account from the outset in order to create scope for their resolution. (3) New method for the revision of local development concepts or plans that facilitates the development of renewable energy projects and establishes the link with the NECP. (4) Prototype for an electronic database solution for the documentation and monitoring of local development

concepts/plans. (5) Public accessibility (at least partially) of the electronic database solution for project development in line with the NECP objectives. The project results will be available in the form of the following products: (1) LINK Guideline for the preparation and revision of municipal development concepts/plans to support the implementation of renewable energy projects at municipal level and to facilitate NECP planning and reporting. (2) LINK digitalisation concept/prototype for the digital implementation of the LINK guideline: The prototype software consists of functional and model elements to enable real-life testing in the municipalities and thus provides a basis for further development beyond the scope of this funded project.
The work builds on the analysis of similar European projects, a municipal case study analysis in the form of the collaboration with the municipalities Baden, Langau, Munderfing, Werfenweng, Hall in Tirol, and Schwoich, as well as semi-structured interviews with stakeholders at the municipal, regional, and federal level.

LINK GUIDELINE AND LINK SOFTWARE

The LINK Guideline consists of six parts with the following contents: (1) Brief description of the NECP and the relevance of municipal development concepts or plans for the NECP. (2) Criteria for municipal development concepts or plans that should be binding in all provinces. (3) Procedure for the revision or preparation of municipal development concepts or plans according to the LINK Guideline (in three steps: status quo survey; analysis regarding criteria and data; processing of the criteria and visualisation of the results). (4) Demonstration of the procedure according to the LINK Guideline on the basis of pilot projects (description of the initial situation - plan with explanations; result after application of the LINK Guideline: plan/visualisation plus explanations regarding renewable energy potentials). (5) Documentation and monitoring for municipal development concepts or plans and their step-by-step implementation. (6) Establishing binding force: a degree of bindingness for the application of the LINK Guideline and how this is to be achieved.
The aim was to develop a concept for the digitised implementation of the LINK Guideline taking into account (1) reduction of administrative burden, (2) transparency and public access of information, (3) interoperability of data and interfaces. For this purpose, collaboration with gizmocraft GmbH was established and software development started in November 2023.

MINIMUM REQUIREMENTS FOR MUNICIPAL DEVELOPMENT CONCEPTS OR PLANS TO FACILITATE THE DEVELOPMENT OF RENEWABLE ENERGY PROJECTS

The definition of mandatory minimum requirements for municipal development concepts/plans is based on the results of interviews, case studies, research of existing spatial planning laws, and project workshops. They serve to support the realisation of renewable energy projects at municipal level, to simplify NECP planning and reporting, to identify conflicting objectives, e.g. nature conservation/biodiversity and energy generation, and how these could be balanced. A detailed description will be provided in the conference paper.

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CONFERENCE TOPIC

This abstract refers to cross-cutting themes “Policies”, “Energy Spatial Planning”.

ON EFFICIENT SOLAR DISTRICT HEATING SYSTEMS – STATUS AND LATEST RESULTS

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SUMMARY

Heat is still the largest energy end-use, accounting for about 50% of global final energy consumption in 2022 and contributing to 40% of global carbon dioxide (CO2) emissions. Regarding the heat supply of buildings, district heating plays an important role and is well-established in many countries. However, most of the district heating networks worldwide are still operated with supply temperatures of 70-120°C (medium-high temperature) often produced by caloric power plants. Solar district heating (SDH) systems can be a valuable alternative to decarbonize these systems. How this can be done most efficiently is investigated within the task 68 *Efficient Solar District Heating Systems* of the International Energy Agency (IEA) from the technology cooperation program – solar heating and cooling (SHC). This contribution presents the latest results of the task regarding comparison of different collector technologies, important digitalization aspects, analysis of available funding schemes and latest efficient SHD installations.

Key-words: *efficient solar thermal systems, district heating, digitalization, IEA, SHC, task*

INTRODUCTION

In order to decarbonize the district heating sector, solar thermal technologies provide a very efficient option, especially when combined with seasonal heat storages. A result of the previous IEA SHC Task on SDH, however, revealed that most district heating networks worldwide, especially the largest ones, still have rather high supply temperatures in the range of 70-120°C (Mazhar et al., 2018). Whereby the heat at these temperatures is still often produced by caloric power plants. In order to find options how to decarbonize such networks by solar technologies as well as how to increase the share of SDH systems in general, the Task 68 - *Efficient Solar District Heating Systems* addresses four main goals as shown in Table 1.

Table 1: Main goals of the new task in order to support the increase of solar district heating (SDH) systems.

	Efficiently providing the heat at the desired temperature level of district heating grids, either directly through solar technologies or indirectly through solar technologies in an efficient combination with other technologies (e.g. heat pumps) with a special focus on the system aspect.
	Increasing the degree of digitalisation of SDH systems in order to achieve a more efficient integration into district heating systems (e.g. by considering solar yield forecasts) and a more efficient processing and use of data for evaluation, advanced controls and automatic fault detection.
	Reducing the costs of solar thermal plants to increase their economic attractiveness and competitiveness, and developing new financing and business models.
	Disseminating the knowledge and results about the potential, areas of application, different solar technologies and their efficient combination with other technologies and systems.

METHODOLOGY

In order to achieve these four main goals, the task is split into four subtasks A – D, considering different solar technologies but focuses even stronger on the system aspect, in order to investigate how to efficiently provide the heat at the desired temperatures by a combination of technologies as schematically shown in the following Figure:

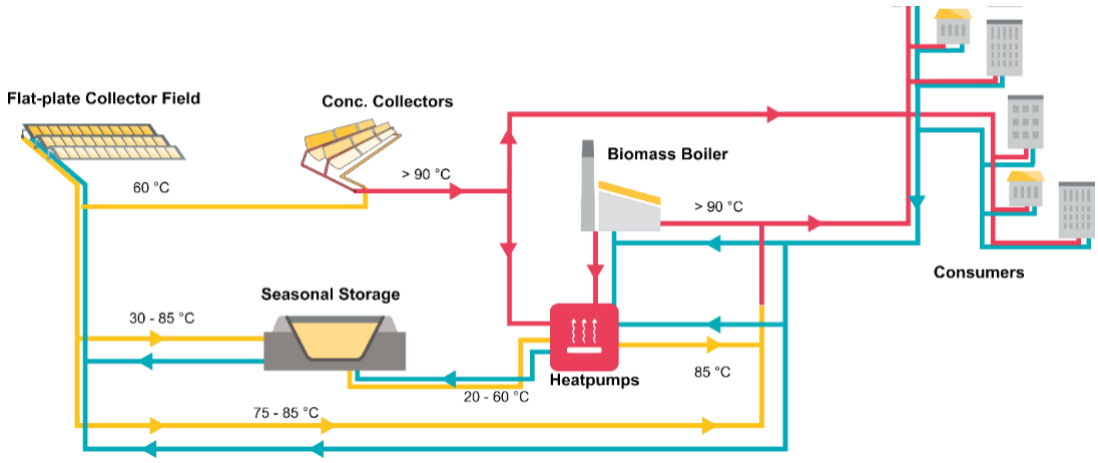

Figure 35: Schematic concept for efficient solar district heating systems combining different technologies

RESULTS

In the contribution latest results of the different subtasks A – D will be presented:

- In Subtask A a sophisticated overview of different collector technologies will be given in order to provide an easier way of comparison, considering also latest technologies like high vacuum flat plate collectors or collectors using high-efficiency lenses.
- In Subtask B key insights of the latest report will be presented on how to efficiently gather, store, distribute and validate data from solar thermal systems together with examples of validated open data sets and how to use them.
- In Subtask C different funding schemes for SDH will be analyzed, showing their differences and telling about their impact and success stories
- In Subtask D an overview of latest efficient SDH installations will be given together with their specific plant characteristics and what makes them special.

Finally, an outlook of the future task work, upcoming events and meetings as well as next reports will be given.

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ACKNOWLEDGMENT

The results leading to this paper are supported by the international energy agency (IEA) and received funding from the Austrian Ministry for Transport, Innovation and Technology (BMVIT).

CONFERENCE TOPIC

Renewable Heating and Cooling including high temperature applications, IT Technologies and Artificial Intelligence

GREENLAB DESIGNER LITE - A TOOL TO ASSIST THE ENERGY SYMBIOSIS DESIGN OF INDUSTRIAL PARKS

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SUMMARY

Many tools exist for analyzing specific aspects of these eco-parks, a comprehensive tool addressing the entirety of an eco-industrial park's design is absent. This gap creates challenges for designers due to the lack of a holistic view of energy systems and their interrelations. Addressing this, this paper introduces "GreenLab Designer Lite," a web-based tool, aimed at aiding designers in creating and managing eco-industrial parks. The tool integrates technologies for sector coupling and demand-side management, offering insights into energy flows and potential industrial symbiosis scenarios.
Keywords: energy symbiosis, industrial symbiosis, eco-park, industrial park, decision-making support, software tool.

INTRODUCTION

Traditional industrial parks follow a linear process in terms of energy consumption and waste production. The energy is produced through resources and the generated waste is discarded which is environmentally costly and unsustainable. With an eco-industrial park, the waste generated from one factory is used as a resource for the next factory, which creates an industrial symbiosis of factories providing energy for each other. This makes the industrial park more eco-friendly and balances waste production and energy consumption. There are eco-industrial parks all over the world, e.g., Kalundborg Industrial Symbiosis (Denmark), Biopark Teneuzen (Netherlands), and Kolmenkulma Eco-Industrial Park (Finland). However, no available software or tool can support the design of eco-industrial parks (or so-called ‘Industrial Symbiosis”).

Many tools provide insight into the modeling and analysis of eco-industrial parks, but they focus on specific aspects and do not consider the whole eco-industrial park. This approach makes it difficult for industrial park designers to design eco-industrial parks since they must learn all the specific tools. Even then the tools do not create an overview of the different energy systems in the park and their symbiosis. For this purpose, a tool needs to be developed that supports the functionalities. Some tools can be used to optimize various aspects of energy systems, but they do not take a holistic approach to designing and optimizing eco-industrial parks. There have been created State-of-the-Art (SoA) methods such as (Gu et al., 2013) focusing on material/energy flow exchanges in an eco-industrial park, (Zhang et al., 2018) focusing on multi-level energy integration, and others, but these methods either focus too much on specific aspects or have not been implemented in practice.

Therefore, the goal of this project is to demonstrate a minimum viable product (MVP) for a decision support tool for creating an industrial symbiosis design. The tool will integrate technologies for sector coupling and demand-side management. These technologies will help the park designer with devising ways to reduce energy investments and assist in calculating dynamic consequences for the current and future infrastructure investments. This project has built upon the initial work of stakeholder interviews including requirement specification, identification and some analysis. The main goal of this project is to realize the functionality of a web-based tool called Eco-Park Designer.

THE WEB-BASED TOOL - GREENLAB DESIGNER LITE

The web-based tool - GreenLab Designer Lite is a functioning prototype of a software tool for decision support on the energy management of eco-industrial parks. The tool aims to integrate technologies in sector coupling and demand-side management to enable industrial park operators to mitigate the need for new energy infrastructure investments in case of new park participants.

GreenLab Designer Lite was developed SDU Center for Energy Informatics, in cooperation with the GreenLab Skive, funded by the Villum Foundation, Denmark. The current version of the tool can be found via the link: https://GreenLabDesignerLite.sdu.dk. The current version can facilitate eco-park designers (refer to industrial park managers who are managing and maintaining an industrial park that already has industrial facilities on site consider how the industrial park can be closer to an "industrial symbiosis" by understanding the current energy flows among existing industrial facilities; what new industrial facilities should be invited to be on board to contribute to their industrial symbiosis profile. Based on the discussion with Greenlab Skive, the functional requirements of the web-based tool - GreenLab Designer Lite are: Authentication; Eco-park overview; Facilities overview (as shown in Fig. 1); Scenario Overview (as shown in Fig. 2); Scenarios comparison (as shown in Fig. 3 and Fig.4).

Fig. 1: Screenshot of GreenLab Designer Lite, Facility setup, an example of industrial greenhouse (electricity and heat consumption)

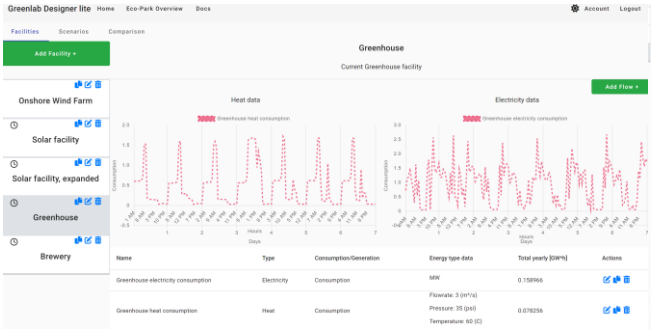


Fig. 2: Screenshot of GreenLab Designer Lite, Scenario Overview

Fig. 3: Screenshot of GreenLab Designer Lite, Comparison Overview (Electricity)

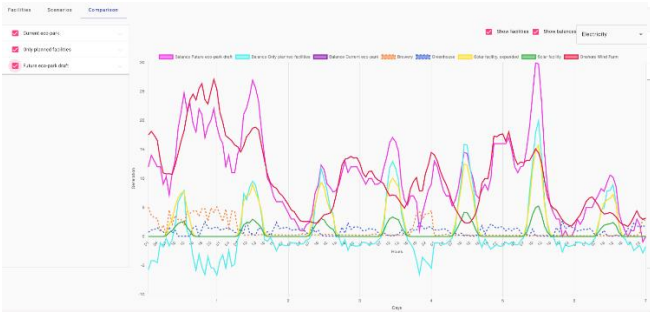
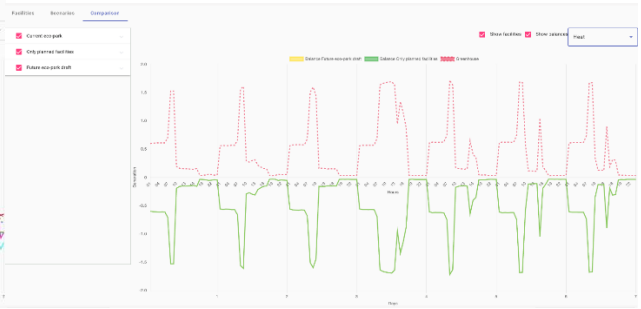


Fig. 4: Screenshot of GreenLab Designer Lite, Comparison Overview (Heating)



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CONFERENCE TOPIC

Approaches towards net-zero/negative emissions in the industry including CCU

ENERGY STORAGE IN HISTORICAL BUILDINGS USING AI APPLICATIONS

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SUMMARY

Historical buildings account for a significant portion of energy use of today's building stock and there are usually limiting energy saving measures due to cultural conservation rules. The purpose of this case study is to evaluate the use of the building structure of a particular historical stone building as a heating battery, i.e. to store thermal energy in the building's structures without physically changing these. With the help of Artificial Intelligence (AI) and machine learning modeling, heat supply is controlled by weather forecast, which enables optimization of energy use and power demand under sustained adequate indoor temperatures. The technique can be combined with temporary reduction of heating without affecting operating temperatures and thermal comfort of premises. The performed study indicates substantial savings in total and peaking energy in the studied building and suggests that the method can be applied to other similar cases.
Keywords: District heating, Artificial Intelligence (AI), Historical building, Energy storage, Peak shaving

PHOTOVOLTAIC AND SOLAR-THERMAL USE CASE APPLICATION COMPARISON WITH WITNESS SIMULATION AND DCF ANALYSIS

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SUMMARY

In this work, we investigate a system of solar and thermal heat collectors in combination with local and electric net storage. The system is implemented in a Witness Horizon simulation model, allowing for the investigation and scenario analysis of different use cases. In a practical industrial application example use-case, using simulation and Discounted Cash Flow (DCF) analysis, the economic feasibility of the best system variant could be calculated. The developed model includes the local consumption and production profile and a separate and, for the first time, integrated DCF model in the generic industrial production system simulation software WITNESS Horizon. This model can be further applied to generic production systems, simultaneously integrating the DCF cost evaluation analysis and following direct economic optimisation. In future research, the method shall be applied to more complex and extended solar-thermal-storage energy production systems and by integrating the production portfolio theory approach by integrating diversified virtual production market aspects and market goal-oriented optimisation.
Key-words: Photovoltaic, Solar-Thermal, EU Green Deal, WITNESS Horizon, DCF analysis

INTRODUCTION

In times of energy crisis and climate change, companies must position themselves more broadly and independently of the fossil energy market. A future investment is increasingly obliged to leave a sustainable footprint, which is demanded on the one hand by the market and on the other hand by politics, especially by the Green Deal of the European Union and the EUTAX regulation. In this context, photovoltaic and solar thermal technology are essential components. This work aims to achieve an economic correlation between the two technologies. Different scenarios with both technologies must be defined and simulated to achieve results for the profitability investment calculation. For the simulation, the program WITNESS Horizon is used. With the simulation results, a profitability calculation for investment, in this case, a Discounted Cash Flow (DCF) method, can be performed. Then, with the help of the results of the DCF method, a strategic decision can be made regarding the investment. In parallel, the EUTAX conformity must still be checked and proven.

MODELLING AND SIMULATION

At first, key parameters had to be defined for the modelling. The “local solar global radiation”, the “available area”, and the “system efficiencies” for the photovoltaic and solar thermal system were defined as key parameters as shown in Table 1.

Table 1: Key Parameters (Gaugg, 2023)

Local solar (sun) global power (Graz, Austria)	1.206,4 kWh /m²
Available area at parking house C&P Immobilien AG	1.222 m²
Photovoltaic system efficiencies	16,57 %
Solar Thermal system efficiencies	35,75 %

Using the key parameters, the corresponding Sankey diagram could be created (Figure 1). In the Sankey diagram, the system boundaries of the model, which is mapped in the Witness Horizon for the simulation, are defined, as well as the associated losses along the value chain.

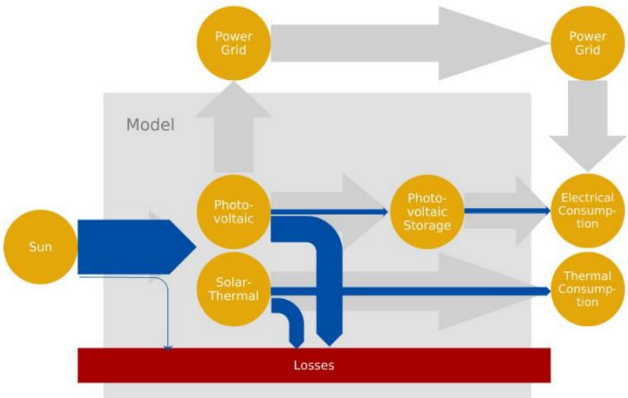

Figure 36: Model for simulation of comparison of photovoltaic and solar thermal (Gaugg, 2023)

The Sankey diagram forms the basis for simulation in Witness Horizon (see Figure 2). Two paths serve as energy sources in WITNESS Horizon. The first path is the sun (Energy_Globalpower), a free but dynamic resource. The second path is the electrical power grid (Energy_PowerGrid), a static system that provides security for a permanent energy supply—the storage for photovoltaic works as an element between electric consumers and photovoltaic systems. The most economical storage size is a result of the WITNESS Horizon simulation. For the sun's energy supply Energy_Globalpower), the hourly arrival of solar power must be calculated using statistical values (Pilger & Podesser, 2010).

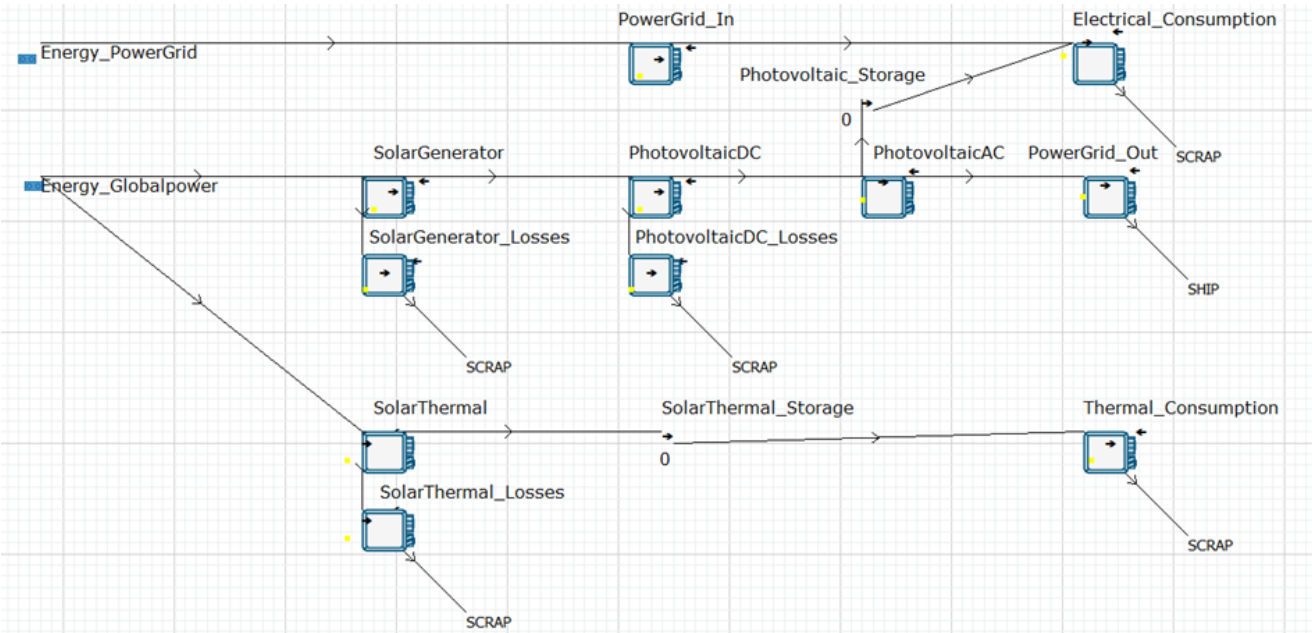

Figure 37: Model and Simulation in WITNESS Horizon (Gaugg, 2023)

The results of the simulation are the electrical energy purchased from the power grid, the electrical energy surplus from the photovoltaic system, which feeds into the power grid and the electrical yield from the photovoltaic system for the own electrical consumers. The results of the previously mentioned values change depending on the photovoltaic storage size. Additionally, the result is the heat consumption. With the results of the different scenarios in the simulation, the DCF method calculation can be performed, and consequently, the most strategically economical decision can be made.

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FLEXMODUL – A MODULAR, FLEXIBLE COMPACT STORAGE SYSTEM

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SUMMARY

In future energy systems volatile production will be dominant. Heating uses a major share of energy in energy systems. Therefore, the deployment of thermal energy storage is key to successful energy management. Sorption heat storage is a promising technology for long-term storage application.
The FlexModul project examines the potential to store heat in a closed fixed-bed sorption heat storage system on a long-term basis for application on household scale from a technical standpoint of view in the field or in field-realistic conditions. Therefore, extensive measurement equipment's to get knowledge of the system and components, e.g. distribution of heat in the sorption storage system during discharging and charging, heat transfer rates, etc. are installed in the demonstrator. With the collected data and the defined KPI's optimizations based on the system layout, operation strategies, component design, etc. are derived and reported to push the compact storage system toward market.
Keywords: flexible, modular, sorption storage system, residential buildings, decentralized, peak-shaving

INTRODUCTION

In recent years, many countries have changed and adapted their energy policies according to the Paris Agreement in 2015. Germany, Austria, and Switzerland all have dedicated plans to phase out coal, nuclear power, and eventually even natural gas. Additionally, they heavily invest in renewable energy resources while needing to ensure a high level of stability and security. Germany's phase out of coal has just been confirmed, committing to gas-powered plants, which are ready to run on hydrogen. Switzerland has recently committed to a 2050 net-carbon-zero strategy, while Austria is targeting 2040 net-zero emissions.
The give a contribution to the above described strategies the overall aim of the project FlexModul is to develop and demonstrate an innovative, modular and compact sorption storage system which is i) easy to scale due to its modular design and ii) easy to adapt to different applications in the heating as well as electricity sector and therefore shows the potential of thermal storages as a cross-section technology that significantly enhances the flexibility of the complete energy system and substantially decrease CO2 emissions. The versatile range of applications of sorption storages will be investigated and two use cases will be demonstrated a) seasonal storage of solar energy for a single-family house, b) Power-to-Heat (P2H) storage for daily storage of fluctuating PV or CHP electricity integrated in a building.
Based on the goals of the project the present report focuses on the highlight of the innovative and flexible part of the system, the design of the components, the optimized operation of the storage system, and report the challenges of the compact storage technology for the demonstrations.

METHODOLOGY, SYSTEM AND RESULTS

The innovative sorption storage system was designed, dimensioned, constructed and initially set up and commissioned in the laboratory as part of the national project FlexModul. Figure 38 shows the principal functionality of the FlexModul system with the two main components: the sorption storage tank and the evaporator and condenser (EC). To the left side of the system the low temperature source is connected and to the right the supply system for space heating and domestic hot water. The sorption storage system was assembled in

the laboratory at AEE INTEC and equipped with a lot of measurement equipment to get knowledge of the system's performance. On another step the control strategy to operate the system efficiently was defined and tested in the laboratory. In general, Figure 39 to the left indicates the operation process for charging of the total system, by using e.g. solar energy or Power-to-Heat (P2H) from a PV system especially during availability and increase the share of renewable energy. As to maximize the efficiency of the system also the sensible heat is stored and can be used for further purposes. On the other hand, Figure 39 shows on the right-hand side the process for adsorption of the system and release the heat for domestic hot water or space heating on demand.

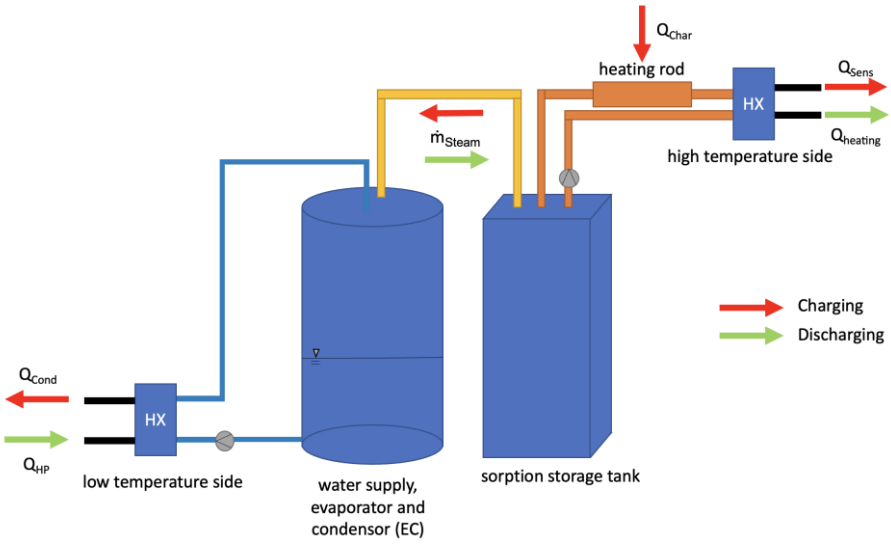

Figure 38: Principal plant setup of the FlexModul system with a Power-to-Heat (P2H) system to charge the storages based on Maresch (2023)

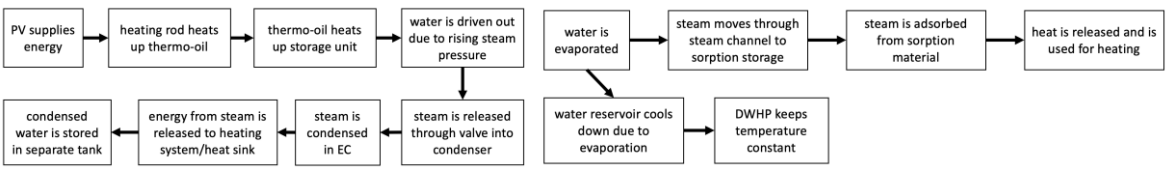

Figure 39: Charging (left) and discharging (right) process scheme

The obtained findings from the laboratory tests will be transferred to the demo sites and will be tested in real field conditions in the year 2024.

Finally, the conclusions of the project are derived from the measurements of the FlexModul system in the field or in field-realistic operation, and assessed with the defined KPI's for techno-economic evaluation. The focus is to push the innovative decentralized seasonal storage system toward market and to also give useful hints for the design, commissioning and field operation of such a system.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Emerging heat and cold storage
- Renewable heating and cooling, including high temperature applications

- Solutions for Energy Efficiency
- Flexibility and Stability of Thermal and Electric Grids
- Coupling of Energy Sectors

TOWARDS A DIGITAL REPRESENTATION OF BUILDING SYSTEMS CONTROLS

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SUMMARY

Monitoring and performance optimization of building systems are essential to ensure an energy-efficient operation of a building. The systematic execution of these processes requires a comprehensive understanding of the building system's control that should be conveyed through detailed function descriptions. However, existing function descriptions are often incomplete, ambiguous, not up-to-date, and primarily available in non-machine-readable formats. To address this challenge, we propose a method for an integral and digital representation of the control of building systems. This methodology utilizes Semantic Web Technologies (SWT) and incorporates existing ontologies, along with the developed PLCont ontology, to describe the control topology and the control functions exported from the programmable logic controllers (PLCs) in accordance with the IEC standard 61131. The methodology facilitates identification and resolution of faulty system behavior, and its application is showcased at a recently constructed seminar center.

INTRODUCTION

The digitalization in the AEC/O (architecture, engineering, construction, and operations) industry is one of the key factors in the ongoing efforts to reduce the energy consumption and CO2 emissions of buildings. Monitoring and energetic performance optimization of building systems offer possibilities to ensure energy-efficient operation. In order to efficiently carry out these processes, a comprehensive understanding of the building system’s control and therefore, an unambiguous and up-to-date function description is required. Currently, these function descriptions only exist in non-machine-readable formats, predominantly PDFs. Furthermore, they are often incomplete, ambiguous, and not up to date as they often only document the design phase. The absence of standardized guidelines for textual function descriptions leads to variations in interpretation and programming during the control implementation. The actual implemented functions are solely found on the programmable logic controllers (PLCs), with no corresponding updates made to the textual descriptions to reflect any adaptations made during the implementation process. This situation hinders the effective application of monitoring processes. Therefore, a methodology for an integral and digital representation of the control of building systems will be presented in the paper.

METHODOLOGY

The objective of this methodology is to describe the complex system relations in building services using Semantic Web Technologies (SWT). To achieve this, the existing ontologies SOSA (Haller et al., 2017), SEAS (Lefrancois et al., 2017) and CTRLont (Schneider, 2019) are used to describe the topology of the control (control actors, sensors, actuators, and their connections). The PLCont ontology, developed as part of the project, establishes the linkage between the topology and the control functions implemented on the PLC. The control functions are exported from the PLC in accordance with the IEC standard 61131. The digital representation can be enriched with information from the planning phase to the operational phase, allowing for a comprehensive digital description of building systems within the framework of Building Information Modeling (BIM) and in compliance with existing standards. Additionally, the implemented control functions can be accessed in an as-

programmed version without the need to directly access the PLC. This facilitates the identification and resolution of faulty system behavior.

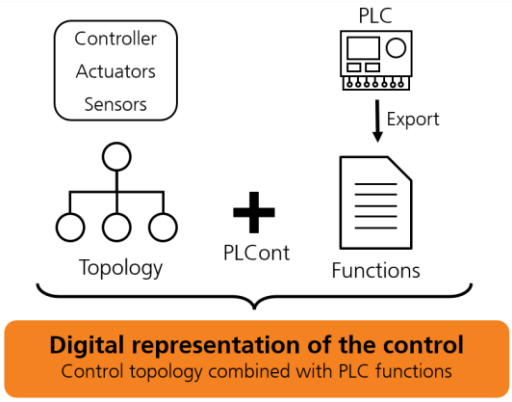

Fig. 1: Schematic overview of the digital representation of the building system's control

DEMONSTRATION

The developed approach is being showcased at a recently constructed seminar center in Germany, which has been handover in January 2023. Currently, a scientific monitoring is in progress to evaluate the building's performance. The utilization of digital representation is used to facilitate this process by providing a standardized description of the control functions and topology. A prototype application has been developed to display the information of the digital representation in form of a digital HVAC schema, accompanied by textual information such as control parameters, the textual function descriptions, and excerpts of the implemented control functions. Furthermore, the control strategies specified during the planning phase as textual descriptions are systematically compared to the implemented control functions and the measurement data. This analysis is done based on the standardized representation of the control and has been completed for an exemplary Air Handling Unit (AHU). The time-series data and the textual functions description show deviations that can only be understood with an in-depth analysis of the PLC code of the control functions. The analysis for a second system, a heat pump, is currently done and will be included in the final paper.

CONCLUSION

In order to increase the efficiency in monitoring and energetic performance optimization processes a standardized description of the implemented control functions is needed. Textual function descriptions alone are often inadequate as they frequently fail to accurately depict the actual implementation, as demonstrated in this study. The methodology presented here addresses this issue. However, the interpretation of the control functions requires a certain understanding of PLC programming and can be time-consuming. Therefore, future research should focus on the development of methods to transform the implemented functions into easily comprehensible descriptions of the control processes.

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CONFERENCE TOPIC

- Digitalization for Future Energy Systems
- Solutions for Energy Efficiency

OPTIMIZING HEAT PUMP OPERATION OF RESIDENTIAL BUILDINGS USING CALIBRATED R-C AND MACHINE LEARNING MODELS, AND WEATHER AND ELECTRICITY COSTS FORECASTS

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SUMMARY

The aim of this research is to improve the efficiency of energy systems using the mass of the building as thermal storage. We present a case study of a residential building, in which a detailed monitoring system was installed to measure, among other parameters, the electricity consumption, the indoor air quality, and the operation of the heating system, based on heat pump. Based on the data collected, a lumped parameter model was calibrated for each of the apartments analysed. The expected results of this work include the detailed prediction of the energy consumption of the apartments, the reduction of the operating costs of the heat pumps and the optimization of the use of electrical energy from the grid.

INTRODUCTION AND CONTEXTUALISATION

The Intergovernmental Panel on Climate Change (IPCC) has identified in its latest report [1] that buildings are one of the most important sectors with potential to reduce Greenhouse Gases (GHG). Innovative techniques are needed to achieve carbon emission goals in buildings. In this sense, the Energy Storage Task 43 of the International Energy Agency (IEA ES Task 43) [2] is committed to analyse the storage for renewables and flexibility through standardized use of building mass. In this context, the ENEDI Research Group of the University of the Basque Country and the Energetic Technology Research Group (GTE) of the University of Vigo, are developing a project [3] which intends to analyse the use of the building mass as thermal storage to improve the efficiency of the renewable energy systems and reducing energy costs.

In this research, we use a case-study building in which two apartments are being monitored in detail since the last 3 years. Using this detailed monitoring data, both R-C and Machine Learning (ML) models will be developed and calibrated to simulate the operation of the apartment. The models will consider the thermal inertia of the apartment since the measurements are being recorded under real operating conditions. Thus, using calibrated models, and considering the weather and electricity costs forecast of the next 24 hours, the operation of the heat pumps will be modified with Artificial Intelligence (AI) models to optimize both the thermal efficiency of the system and the cost of the energy. Following Fig. 6 shows a schematic representation of the methodology of the research.

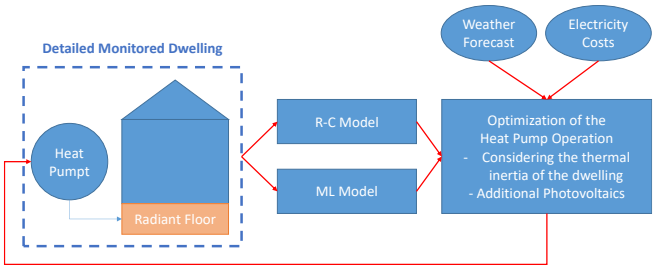
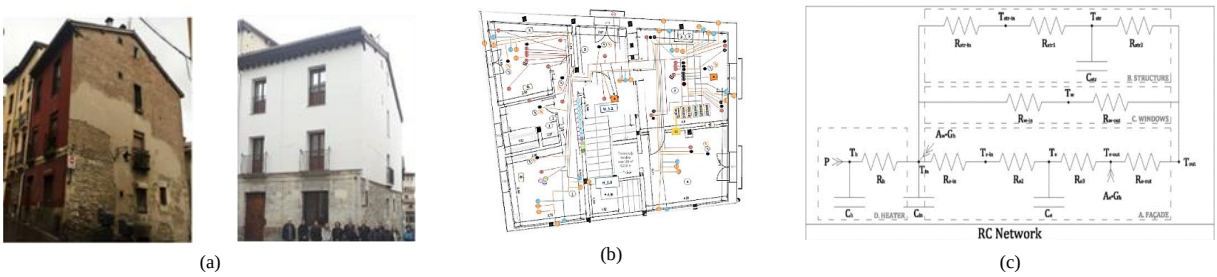


Fig. 6: schematic representation of the methodology of the research

MATERIALS AND METHODS

The case-study building used is located in the city of Vitoria-Gasteiz, in the north of Spain. It is a residential building consisting of three floors with a small apartment in each of them. The building underwent a renovation in 2019. The external envelope was improved and high efficiency heat pumps were installed to supply heating and DHW. Fig. 7 shows a picture of the residential building and an example of the distribution and equipment of metering in one of the apartments analysed. A detailed monitoring system was installed after the renovation process. The electricity consumption of the dwellings and of the heat pumps, the indoor temperature, relative humidity or CO_2 concentration, and the temperature of the fluid of the heating system, among other parameters, have been measured since 2019.



(a) (b) (c)

Fig. 7: (a) picture of the analysed building after-before the renovation process, (b) layout of the first floor apartment with instrumentation (c) example of RC lumped parameter model.

Thus, using the detailed monitored parameters, a RC-network model will be calibrated for each of the analysed apartments. Lumped parameter models have proven to be one of the best options to accurately characterize the real thermal behaviour of buildings [4], while being agile to be used as a reference model for AI-based control systems [5]. These models of lumped parameters also make it possible to quantify the viability of real buildings as energy accumulators for the optimization and regulation of consumption control, at the user level, and production at the general grid level [6].

The expected results of this work will therefore consist of:

1. Predict in detail the energy consumption of the apartments, taking into account the performance and thermal inertia of the dwellings.
2. Reduce heat pump operating costs, and optimize the use of electrical energy from the grid, with weather and energy price forecasting.
3. Analyse the viability of the current building stock as an efficient energy storage system and determine the optimal performance of new buildings for this application.

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CONFERENCE TOPIC

Flexibility and Stability of Thermal and Electric Grids

ENERGY SAVINGS, ENVIRONMETAL IMPACTS AND MONITORING RESULTS OF A PUMPED SOLAR WATRE HEATING SYSTEM AT KATUTURA HOSPITAL MATERNITY WARD, NAMIBIA

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SUMMARY

According to Moschik 2022, the SADC region is blessed with solar radiation between 1800-2400 kWh/m^2. Nevertheless only 0.3 % of the worldwide solar thermal capacity is installed in the Sab-Saharan African Countries. Therefore, the main goal of the Southern African Solar Renewable Heating and Cooling Initiative (SOLTRAIN+) project funded by the Austrian Development Agency is to contribute to the transformation of the energy system to a sustainable, affordable and carbon-free system. This will be done by the implementation of Renewable, Heating and Cooling (RHC) systems in the targeted sectors: buildings, industry & commerce, tourism and hospitals, and enable this by a holistic capacity building. RHC technologies are solar thermal, heat pump and energy efficiency. This study therefore intends to evaluate and produce energy balance, based on real data recorded from June 2023 to January 2024 on a 120m^2 collector area with 8000 litres storage tanks, and 22kW heat pump, installed at Katutura State Hospital Maternity Ward.

Key-words: *Solar Water Heating, Monitoring, heat pump, Energy efficiency*

INTRODUCTION AND BACKGROUND

The Namibia Energy Institute (NEI) is a national research Institute established by the Ministry of Mines and Energy (MME) and hosted at Namibia University of Science and Technology (NUST) to support the development and dissemination of knowledge, skills and good practices towards a safer, more secure and sustainable energy system in Namibia. Since 2009 the NEI has been implementing the Southern African Solar Thermal Training and Demonstration Initiative (SOLTRAIN) whose aim is to support the Namibian Government to implement the Cabinet Directive of 2007 on solar water heating and Solar Thermal Roadmap. By doing so, the institute build capacity in the field of solar thermal technologies, and promote the uptake of solar thermal systems and to ensure selection of quality products and workmanship in order to guarantee optimal performance during the lifetime of solar thermal systems. Additionally, SOLTRAIN supports the national policies on energy for sustainable development by creating new jobs in Small and Medium Enterprises, through funding of flagship demonstration systems and strengthening the local support mechanisms for solar thermal systems.

The Namibia Government has shown a political will and commitment towards the roll-out of solar thermal technologies and other renewable energy technologies through well-articulated policy and strategy documents such as the 2007 Cabinet Directive on solar water heaters, the 2016 Solar Thermal Technology Roadmap, which has been adopted into the National Renewable Energy Policy, and the Nationally Determined Contribution (NDC). The Solar Thermal Technology (STT) Roadmap of Namibia outlines the country's path towards attaining a 1.5 million m² of solar collector area with an average micro target of 0.5 m² installed per inhabitant by 2030. Nationally Determined Contribution (NDC) aims to achieve a 91 % reduction of greenhouse gas (GHG)

emissions by 2030 by increasing the share of renewable energy in the country's energy mix through various initiatives.

The Katutura Hospital complex consists of many buildings with the largest solar water heating system in the country, which is made up of 8 separate subsystems. These systems are Ground Floor East (200 m^2), Maternity and Tuberculosis Wards (100 m^2), Main Tower hospital (200 m^2), Operating Theatres (100 m^2), Ground Floor West (200 m^2), Kitchen (100 m^2), Nurses' quarters (100 m^2), and Doctors' block (100 m^2). The total systems were designed to provide over 50000 liters of hot water per day. Currently only Maternity Ward System is functional. As a result of seven solar water heating systems not being functional, the departments have resorted to using various heating appliances using grid electricity, and thereby defeating the purpose of the installed solar water heating system.

METHODOLOGY

The study intends to evaluate and analyse real data recorded from June 2023 to January 2024 on a 120 m^2 collector area with 8000 litres tanks 22 kW Heat Pump, as well as 6 kW electrical element used as back up installed in each of the two fresh water tanks for the system installed at Katutura State Hospital maternity ward. Heat meters are installed in the collector loop, to record data from the solar station, cold water inlet, hot water outlet, heat pump outlet as well at the circulation pump. Energy meters are also installed to measure electrical consumpsion of the electrical elements.

EXPECTED OUTCOME

NEI has been monitoring the previous system with the support of AEE INTEC under the SOLTRAIN project hence it is a usual experience for the institute. An energy balance of the system will be developed to understand the performance, contribution of the system to the production of hot water at Katutura State Hospital Maternity Ward in terms of energy savings and avoided carbon emission will be calculated. The data will be presented to the Katutura State Hospital management and to other stakeholders such as Ministry of Environment Forestry and Tourism, and the Ministry of Mines and Energy to influence the refurbishment of other seven systems currently not functioning. It will support the installation of new solar thermal systems, providing awareness and give feedback to installers on the quality.

CONCLUSION

The study will contribute to NUST's Green Vision of 2030, which aspires to contribute towards a future where all energy is consumed from sustainable sources and sustained by a public that understands and values the social, economic, and environmental benefits that green energy provides to our communities, our nation, and beyond through an integrated green energy creative value chain.

More than 50% of the world's energy demand is required by heat. Monitoring and measuring the operation of solar systems are proofing the benefit of the system. Solar thermal system are simple, are able to compete with other technologies, and are able to play significantly role to contribute to CO_2 reduction.

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CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Special focus on developing countries
- Approaches towards net-zero/negative emissions in the industry including CCU

This work is supported by the Austrian Development Agency (ADA) and ERP-Fonds (project SOLTRAIN+)

INTEGRATED DESIGN AND OPERATIONAL OPTIMISATION FOR DISTRICT HEATING NETWORKS: HIGH TEMPERATURE STORAGE AND HEAT PUMPS

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SUMMARY

District Heating Systems (DHS) are foreseen as one of the main solutions in the heating transition. Their investment-heavy nature makes it challenging to establish viable business-cases for supply-side. A integral techno-economic network optimization with minimal a-priori assumptions, the Dynamic GROW Model, is utilized for the early planning phase. GROW optimizes the investment costs and operational strategy utilizing a Mixed Integer Linear Problem approach, cracking the chicken-egg problem. Linearization of the physics are chosen with a conservative impact on the costs estimates. The ideal end scenario is optimized, for the placement and size of sources, storage components and pipes together with the operational strategy. This abstract proposes an extension of the workflow to enable modelling the seasonal storage in combination with a heat pump (HP) to upgrade the discharge temperature which drops due to heat losses.

Keywords: techno-economic optimisation, seasonal thermal energy storage, district heating network, heat pump.

INTRODUCTION

The Netherlands, with over 90% of homes heated by natural gas, will use DHS for up to 40% (Planbureau voor de Leefomgeving, 2017) of future heating systems in the built environment, according to ambitions of the Ministry of Economics and Climate. Currently, municipalities are facing the challenge of making heat transition plans for their neighbourhoods up to 2050 to move away from natural gas. The design of a DHS is based on multiple factors with a range of different considerations depending on the stakeholders and possibly the status of a pre-existing network. In the planning phase, an initial design with assets and pipes is often selected out of a few evaluated scenarios. This does not lead to an optimal integral design as simply too many possibilities are left unconsidered, e.g. combination of sources/storages, network temperatures, pipe routing, operational strategies and combinations of the afore mentioned.

The GROW workflow (Rojer, Janssen, & Klauw, 2023), (TNO Jim Rojer, 2023) has showed that design optimisation can have a significant role in reducing the Total Cost of Ownership (TCO). GROW utilizes simultaneous optimisation of CAPEX and OPEX over the lifetime to enable optimal trade-offs. This research extends the physical modelling approach with a method to integrally consider varying network temperatures. It is utilized to more accurately model HT-ATES with HP combination.

MILP BASED WORKFLOW PHILOSOPHY

High level DHS design requires a suitable operational strategy in an early phase of the design process to properly determine the overall system performance and costs. This early phase is characterized with many uncertainties in input data, and the many possibilities to change choices of the design. Nevertheless, these choices set the boundaries for interactions between sub-parts of the DHS, and thus can limit detailed design afterwards. Trade-offs taking into account the interaction between assets, but also trade-offs between design and operational strategy are key in reducing the overall system cost.

In earlier work GROW was developed, utilising a MILP approach to optimise the overall system costs. The objective is to minimise the TCO consisting of all costs, CAPEX, incorporating sizing and placement decisions, and OPEX, incorporating operational decisions, for each asset, over the time horizon. Thermal power, volumetric flow, and head constraints are added for every type of asset to approximate the (steady-state) physics induced by that asset, ensuring a hydraulically feasible solution whilst linearizing the physics. Energy changes were modelled with the assumption of a constant temperature throughout the network. The linearization made ensure that the effects of these assumptions are relatively small and conservative to the objective function outcome. In this abstract a varying temperature will be enabled in parts of the system. Details on the physical model are in progress of being published in a separate paper.

DEVELOPMENT HT-ATES AND HEATPUMP MODEL

Supply and return temperature were considered constant throughout each hydraulically coupled network in the MILP approach (Rojer, Janssen, & Klauw, 2023). The high temperature seasonal storage (HT-ATES) has significant heat losses over time, resulting in reduced thermal power and temperature drop when discharging. Configurations with a HP or another asset to upgrade the heat is gaining attention (Pieper, 2023), (HEATSTORE, 2021). Without upgrading the temperature, the seasonal storage cannot be used to its full potential as the cut-off temperature will be relatively high.

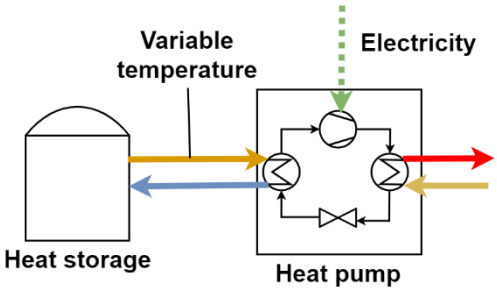

Fig 1: Schematic overview HT-ATES heat pump configuration

The advantage of computational speed of MILP needs to be retained for early phase integral optimization with many decision variables. Therefore, a linearised state for the temperature of the hydraulically decoupled network between the HT-ATES and HP is developed. The seasonal storage gets an additional variable representing the temperature state, which is linked to the heat losses of the storage.

The constant supply and return temperature is replaced with an integer variable for both. The optimization can chose out of a finite set of possible supply and return temperatures for each hydraulically decoupled network. A sufficiently fine resolution allows to model the temperature variation by creating a separate hydraulic system between the HT-ATES and HP, subject to: $T_{HTATES} \geq T_{supply,i}\delta_i, \ \forall i \in S_{Toptions}$ (eq. 1).

The COP of the heat pump is a linearised with the supply temperature on the primary side. As the COP during discharging of the HT-ATES will go down, more electricity and a larger sized heat pump is required. This both influences the CAPEX and OPEX and results in a more accurate sizing of the corresponding assets.

USE-CASE RESULTS

The Rijswijk use-case has indicated a significant reduction in costs when HT-ATES is utilised, with the previously developed framework. The new approach will be applied to the Rijswijk use-case again, which should show more representative use of the seasonal storage. The results will better represent the electricity cost with varying COP for the HP and the shorter more realistic discharge period due to temperature cut-off.

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CONFERENCE TOPIC

Flexibility and Stability of Thermal and Electric Grids, Emerging heat and cold storage, Coupling of Energy Sectors, Spatial Energy Planning.

HEAT PUMPS WITH REFRIGERANT WATER BELOW THE FREEZING POINT - CLIMATE-FRIENDLY HEAT RECOVERY VIA EXTENDED RANGE AND LIFT OF TEMPERATURE

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SUMMARY

Absorption refrigeration systems with the working pair of water and aqueous lithium bromide solution are in general not used to provide cooling below 0 °C, as the refrigerant water would crystallise in the evaporator.
The German Federal Ministry of Economics and Climate Protection (BMWK) funded the use of the environmentally friendly and harmless refrigerant water in sorption refrigeration systems at and below the freezing point in the "SubSie - sorption evaporators for boiling temperatures below 0 °C" research network. It was shown that this limit can be undercut by suitable process control.
In the embedded research project "GALuWap" (FKZ 03EN2005), approaches to solutions that appear to be expedient were investigated at ZAE Bayern in parallel with renowned institutes such as Fraunhofer ISE, RWTH Aachen or ILK Dresden and are presented and discussed here. Initial measurements and operating experience on a functional model on a real scale are intended to make the opportunities and risks tangible. This will allow scientists, planners and customers to consider thermally driven heat pumps for efficiency enhancement measures in extended fields of application and to involve manufacturers who are already realising and realized initial projects in this area in advance.
KEYWORDS: two-stage LiBr-absorption heat pump, fossil free cooling below 0 °C, high temperature lift, waste heat utilization in industry, thermally driven air heat pump

INTRODUCTION, MOTIVATION AND BENEFIT

Thermally driven heat pumps and cooling systems can preferably be operated with waste heat from industrial plants or in food processes. Nowadays, these systems are also being implemented in an economically attractive way to increase the efficiency of district heating supplies, particularly in combination with biomass heating plants or combined heat and power plants. In this context, it is also interesting to consider the utilisation of the environmental heat source air, the freezing cooling of foodstuffs as well as their production. Therefore the systems have to reach temperatures below the freezing point of water. In common, this is meant to be a insuperable limit for absorption-systems with water as refrigerant. As the "GALuWap" research project and other realized applications have shown, this limit can be undercut for some system types. These include, in particular, machines that use aqueous lithium bromide solution as an internal process medium. This substance is one of the best known and most efficient media for thermally driven heat pumps and chillers and is used worldwide and in large numbers for air conditioning and refrigeration purposes.
As lithium bromide (LiBr) has a freezing-point-lowering effect, it is obvious that the refrigerant in such systems should be enriched with this salt to enable appropriate operation below 0 °C. This necessarily involves suitable salt management in the refrigerant circuit. In addition, the salt concentration in the absorber and desorber must be adjusted. The crystallization limit of the salt solution has a particularly limiting effect. Further limitations result on the one hand from reduced heat transfer on the process side and on the other hand from the heat transfer medium, which becomes very viscous at temperatures around -10 °C. This can be remedied by optimizing the geometry of the heat exchanger tubes and appropriate tube installations, for example.

Overcoming the challenges of this extended operating mode opens up new fields of application, for example for the use of waste heat or geothermal energy. The use of heat pumps with air as an environmental heat source is also possible: even in the cold season, energy can be recovered at a low temperature level with the help of thermal drive energy, so that the use in older buildings is possible. The technical insight into the opportunities and risks of operating absorption chillers and in particular the shell-and-tube evaporator with water as a refrigerant below the freezing point helps to reliably develop and improve systems.

SYSTEM CONCEPT, KEY FIGURES & EXPERIMENTAL SET-UP

The approach of the project was a gas-fired absorption heat pump using the ambient heat source air down to - 10°C with a heating capacity of about 120 kW. The absorption heat pump can provide temperature lifts up to 70 K. An annual efficiency of 1.3 can be achieved.
To reach the temperature lift, a so-called double-lift design of the absorption heat pump is required. This means, that the heat is lifted up two times and therefore two evaporator/absorber-vessels at two different pressure-levels are needed as shown in figure 1.

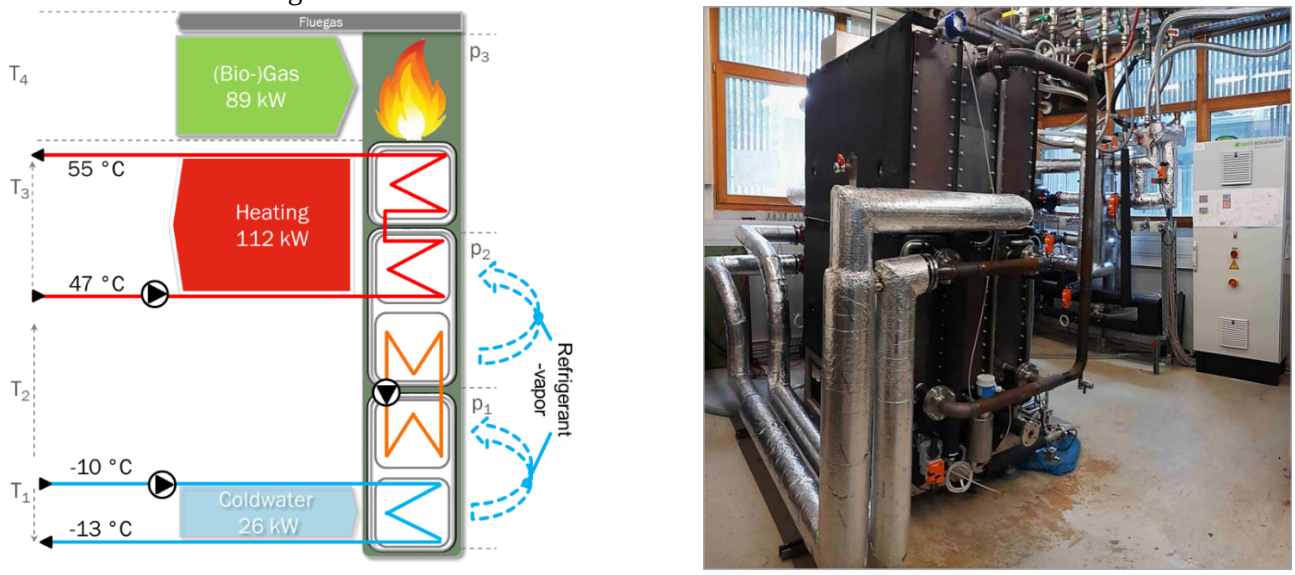

Fig. 1: scematic double-lift process and picture of the laboratory-installation

Core-piece of the whole system is the salt-management in the refrigerant, which offers opportunities for sub-zero-applications of any LiBr-based absorption-chiller or heatpump. The research in the laboratory on the scaleable system shows good results.

CONCLUSIONS AND OUTLOOK

Recommended and already realized applications are e.g. breweries, heat-pump-extension in district heating and further more. As the new findings shall reach decision-makers and planners, a collaboration with associations and European manufacturers now ensures, that the impact on energy-saving and efficiency in industries can be broadened. The exchange with customers as well as with manufacturers certainly shows interest in integrating the technology presented into their own processes.

CONFERENCE TOPIC

Conference Topics this abstract refers:

- Renewable heating and cooling, including high temperature applications
- Excess Heat Energy and Resource Recovery from Low-grade Sources
- Solutions for Energy Efficiency
- Future District Heating and Cooling Technologies

DEVELOPMENT OF AN INDUSTRIAL FLUIDIZED-BED REACTOR SYSTEM FOR THERMOCHEMICAL ENERGY STORAGE BASED ON CAO/CA(OH)2

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SUMMARY

The material system $CaO/Ca(OH)_2$ utilized in fluidized bed rector systems shows a high potential for a thermochemical energy storage in industrial applications. However, particle stability and limited storage power are the most relevant challenges for the scale-up of this technology. This work focuses on the development of such a storage system and the optimization of the operating conditions in terms of fluidization behaviour and reactor performance. Furthermore, the efficient integration in the energy system of industrial sites from a techno-economic point of view is a crucial aspect for a future application of the storage system. Results from energy system simulations show a significant increase of the system flexibility leading to a reduction of the overall costs for a direct coupling of the storage system with industrial steam grids in comparison to state-of-the-art technology.

Keywords: Thermochemical Energy Storage, Fluidized Bed Reactor, Particle Stability, Techno-Economic Analysis

INTRODUCTION

Thermochemical energy storage systems based on the material $CaO/Ca(OH)_2$ offer a high potential for an increased flexibility of industrial applications within the temperature range of 400°C – 600°C. Thermal energy can be stored in a reversible reaction:

$$CaO\ (s) + H_2O(g) \rightleftharpoons Ca(OH)_2(s) + 104\ kJ/mol \tag{1}$$

The material system is characterized by low costs, high availability, high storage density, nontoxicity and fast reaction kinetics [1]. However, the low heat conductivity of the material limits the power input and output of the storage reactor. Therefore, fluidized bed reactor systems are regarded as one possible solution to increase the storage power due to the improved mass and heat transfer. One major challenge of this reactor and reaction system is the mechanical stress on the particles leading to particle breakage and degradation throughout the storage cycles. There are two approaches to improve the particle stability: material modification or optimization of the operating conditions. This works focuses on the latter and aims for the identification of the optimal operating conditions for thermal energy storage systems.

Regarding equation (1), part of the reaction enthalpy leaves the storage reactor as steam in the discharging operation. In addition, steam needs to be provided to the storage reactor during the charging operation. For industrial applications, an efficient integration in the energy system is mandatory. Direct utilization of the steam from the storage reaction shows the most efficient way to achieve this [2]. In this regard, an operation of the fluidized bed reactor in pure steam atmosphere is required to reduce the energetic losses for a downstream gas separation. Although the fluidization in pure steam atmosphere leads to further challenges for the fluidized bed operation, the energetic and economic advantages predominate. One promising industrial integration is the direct

coupling of the storage system with an industrial steam grid. In this work, this concept is evaluated in regards of energetic efficiency and economic viability.

EXPERIMENTAL RESEARCH ON THE STORAGE SYSTEM

The operational behavior of the storage material is investigated in various fluidized bed reactors of different scale (0.2 – 30 L reactive volume). Typically, multiple storage cycles are performed by temperature swing operation around the equilibrium temperature. After a certain number of cycles, particle samples are taken in order to analyze the chemical and physical properties (conversion, particle size distribution, density, pore size distribution, etc.). In Fig. 8, the development of the particle size with increasing numbers of storage cycles is shown for the pilot-scale reactor. The particle size decreases for higher storage cycle numbers indicating the significant effect of particle breakage. By adjusting the relevant process parameters, the optimal operating conditions are identified.

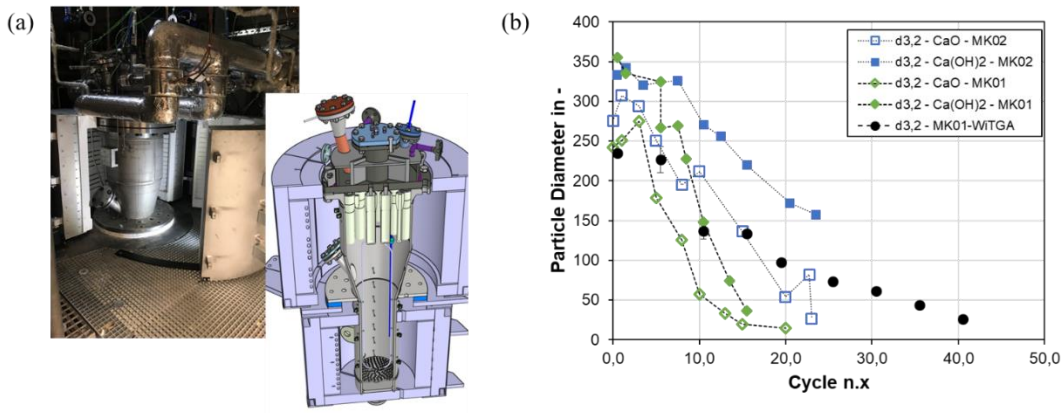

Fig. 8: Experimental investigation of the particle stability during fluidized bed operation: (a) pilot-scale reactor, (b) development of the Sauter mean diameter with storage cycle number. [3]

TECHNO-ECONOMIC ASSESSMENT FOR INDUSTRIAL APPLICATIONS

As stated in chapter 0, a promising integration option is the direct coupling of the storage system with an industrial steam grid. The basic concept is illustrated in Fig. 9. The charging reactor uses electricity either from the grid or from own production of the industrial park to provide the energy for the dehydration reaction. The discharging reactor provides high-grade process steam to enable the shutdown of other generation units in unfavorable operating points (e.g. costs). Techno-economic evaluations and energy system simulations of the storage integration in industrial parks have been performed in order to obtain the operational behavior and the reduction of fuel, costs and CO_2 emissions in comparison to a conventional fossil fuel fired CHP plant for steam generation. Results show that the storage integration leads to significant cost savings for the industrial site with amortization periods well below 10 years.

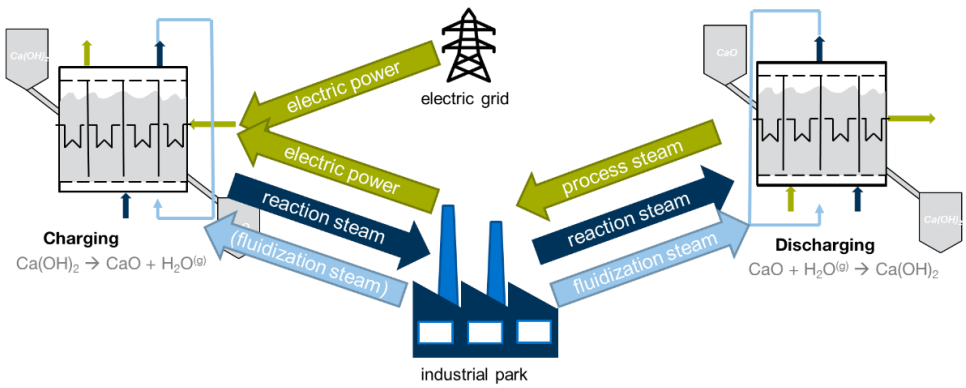

Fig. 9: Integration of the storage system in an industrial energy system

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CONFERENCE TOPIC

Emerging heat and cold storage

WIND-POWERED HEATING 2.0 –SPACE HEATING WITH EXCESS POWER FEATURING GRID STABILIZATION

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In central and northern Europe winter season typically is characterized by an increased number of storms compared to summer. These strong wind events typically occur at a frequency of one to two week and have a duration of five to nine hours. The resulting power overproduction puts high loads on the German power grid and creates significant costs for the wind park owners, grid operator and finally for the customers. Direct redispatch costs alone were 761 Mio € and 6,1 TWh of renewable production were shut down and substituted by fossil generation. Wind Heating 2.0 is an innovative heating concept that charges a building every 1-2 weeks as a power-to-heat application, stores it and provides space heating and domestic hot water until the next strong wind event, without requiring additional power from the grid. With these operations Wind Heating 2.0 can reduce the load on the grid during high stress periods, while a heat pump can be deactivated for a few hours only. A 7.5 days control is developed that incorporates a prediction of the buildings heat demand, electricity stock prices and grid-status. Also, three different storage concepts are developed and presented here: A High Temperature Stone Storage (HTSS), Building Componentes with integrated long-term Storage (BCS) and a Waterbased Thermal Storage (WTS). These new technologies proved in in situ experiments to be able to bridge a period of 1-2 week in high performance residential buildings without requiring additional thermal energy.

PERFORMANCE ASSESSMENT OF NOVEL TRANSPARENT INSULATION MATERIALS FOR INTEGRATED STORAGE COLLECTORS

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SUMMARY

Quite similar to the greenhouse effect in the atmosphere, the main functional principle of transparent insulation structures is based on high solar transmittance and high infrared absorbance. The infrared absorbance is also related to carbon-oxygen bonds in TI materials. The main objective of this study was a systematic and comprehensive evaluation of a novel sorbitol- or bio-based polycarbonate (bio-PC) for TI structures and hot water collector systems. Therefore, the bio-PC was characterized on polymer film level using optical and mechanical methods. Moreover, the technical and ecological performance of such structures in different hot water collectors and systems was modelled and simulated. The experimental characterization revealed an excellent property profile for the novel bio-PC outperforming well-established materials such as cellulose acetate or fossil-PC. Current research is focussed on the collector and hot water system level. While the modelling tools are implemented, there is still a lack of input data especially for life cycle analysis.

INTRODUCTION

The main driver for climate change is the annual fossil CO_2 emissions, which amount to about 40 bill tons/a worldwide (IEA 2023a, 2023b). Due to the asymmetric structure and the polarity of CO_2, this greenhouse gas is absorbing heat radiation while it is fully transparent for solar irradiation. The current greenhouse gas level in our atmosphere has increased from 325 ppm in 1970 to already 420 ppm in 2023 (Keeling and Keeling 2017).
Quite similar to the greenhouse effect of CO_2 in our atmosphere, C-O bonds play also a main role in engineering transparent insulation structures (Wallner et al. 2004). Their functional principle is also based on the greenhouse effect characterized by high solar transmittance and high infrared absorbance (Wallner et al. 2005a, 2005b). For solar heating and cooling, transparent insulation structures are well established for integrated storage collectors (e.g., Solcrafte), but also for advanced flat-plate collectors (e.g., TIGI Solar). The transparent insulation honeycomb structure is positioned in between the front glass cover and the absorber.
So far, fossil-fuel based transparent insulation materials such as polycarbonate (PC) were commercialized and used. Moreover, cellulose derived top-down materials such as Cellulose acetate (CA) structures are commercially available (e.g., Wacotech). Both of them have significant disadvantages. While fossil-fuel based PC shows an average infrared absorbance and is prone to yellowing upon UV ageing, CA requires plasticizers which get lost over time resulting in significant embrittlement of the honeycomb structure. Just recently, a novel bottom-up biopolymer (bio-PC) based on sorbitol derivatives has been introduced into the market and commercialized. Similar to synthetic, fossil-fuel based plastics, the sorbitol-based bio-PC is manufactured from well-defined small molecules or monomers. The main objective of this paper was to evaluate the potentials and limitations of this new class of bottom-up bio-PC for transparent insulation structures in integrated storage or flat plate collectors.

EXPERIMENTAL & MODELLING

A commercially available sorbitol-based bio-polycarbonate (bio-PC; brand: DURABIO; manufacturer: MITSUBISHI Chemicals) was used to prepare thin films with a thickness ranging from 20 to 100µm and to

investigate the main optical properties in the solar and infrared wavelength. Moreover, standardized specimens were injection moulded and characterized by Dynamic Mechanical Analysis as to the long-term creep behaviour. To assess the performance on collector level, numerical simulations were carried out for integrated storage and flat plate collectors with transparent insulation structures based on fossil-PC, CA and the novel bio-PC grade. Moreover, a life cycle assessment was carried out evaluating the effect of these transparent insulation materials on the energy-pay-back time and the environmental impacts of the investigated solar heating systems for hot water preparation (Kicker et al. 2017; Kicker et al. 2018a; Kicker et al. 2018b; Kicker et al. 2019). Within IEA SHC Task 69, these collector systems should be compared comprehensively to well-established flat-plate or vacuum tube or photovoltaic module solar hot water systems.

RESULTS AND DISCUSSION

The optical characterization of the novel bio-PC showed a high hemispherical transmittance in the solar radiation range along with rather low scattering. The solar reflectance was about 8 %, which is comparable to polymethyl methacrylate or cellulose acetate indicating a refractive index of about 1.49. Hence, the macromolecular structure of this sorbitol-based material consists of aliphatic ether groups and ring structures quite similar to cellulose acetate. The main difference to CA is that the aliphatic ether rings are connected with an ester group (see Fig. 1).

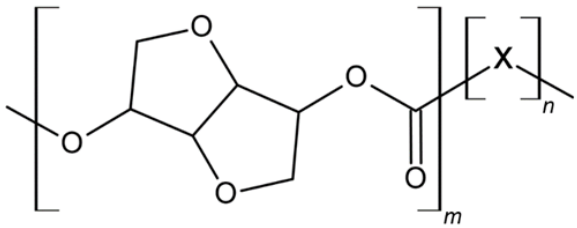

Fig. 1: Chemical structure of the novel sorbitol- and bio-based polycarbonate (bio-PC)

In the thermal radiation or infrared range, the novel bio-PC was found to provide remarkable infrared absorption values, which were even higher than for the so far best performing cellulose acetate materials at a given film thickness. For 50 µm thick transparent insulation films, an infrared optical thickness was deduced which was about 20% higher compared to CA and a factor a more than 2 better compared to fossil-fuel based PC. The excellent infrared absorption of bio-PC could be attributed to a rather high density of C-O-C bonds in the macromolecular chain.

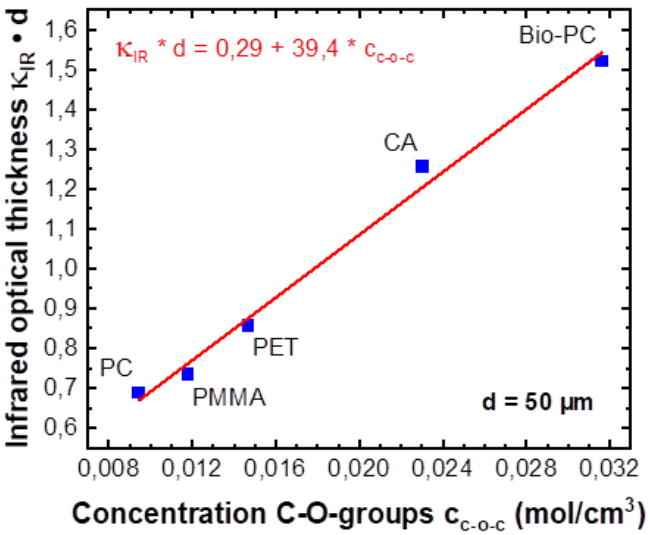

Fig. 2: Correlation between infrared optical thickness and C-O-C concentration for different transparent insulation materials (PC, PMMA, CA, bio-PC) at a thickness of 50µm.

By Dynamic Mechanical Analysis (DMA), a glass transition with a peak in the loss or damping factor at 130°C was deduced for the investigated bio-PC grade. That's about 20°C below the well-established fossil-PC, but about 30°C higher compared to CA. The creep curves generated by DMA and modelled by time-temperature shift principles, revealed for bio-PC a non-critical material deformation at an average application temperature of 30°C and an assumed lifetime of 30 years.
Regarding the performance on collector level, simulations are still ongoing. Due to the better overall greenhouse properties ascertained on film level, a significantly improved collector efficiency is expected. For life cycle assessment, no specific ecological impact data were found for bio-PC. Hence, input data for the raw material sorbitol will be used and extrapolated to bio-PC considering published data for polycondensation of polyesters. Finally, it should be mentioned data high quality input data for thermosiphon and photovoltaic hot water collector systems are also still missing. Hence, the research work within the next few months will be focused on the latter issues.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Renewable heating and cooling, including high temperature applications
- Life Cycle Assessment

STREAMLINING KINETIC CHARACTERIZATION FOR THERMOCHEMICAL ENERGY STORAGE SOLUTIONS

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SUMMARY

This research advances Thermochemical Energy Storage (TCES) by assessing the Na2S hydration-dehydration reaction kinetics using the Shuffled Complex Evolution (SCE) optimization algorithm. The SCE approach efficiently calibrates a multi-step reaction rate equation, streamlining the complex parameterization process inherent in TCES materials. This method proves particularly advantageous in multivariate contexts, traditionally challenging to address due to their complexity and the time-intensive nature of conventional methods. The SCE-derived model offers accurate predictions of reaction rates, essential for the design and optimization of Na2S-based TCES systems. The accuracy of the model predictions however is fundamentally tied to the quality of the underlying kinetic model, emphasizing the need for a thorough understanding of the underlying physics.
Keywords: Thermochemical Energy Storage, Sodium Sulfide, Reaction Kinetics, Shuffled Complex Evolution

INTRODUCTION

Thermochemical Energy Storage (TCES) represents a promising avenue in energy storage, particularly for residential sectors, with its potential to balance renewable energy supply and demand and reduce grid dependence. Salt hydrates, with their significant energy storage capacity and cost-effectiveness, are emerging as viable solutions for sustainable home energy systems, characterized by low heat loss and sustained long-term efficiency. Na2S is particularly notable, boasting exceptional energy storage density. However, effective TCES solutions rely on a deeper kinetic understanding during its hydration and dehydration cycles. Addressing this knowledge gap, this study leverages the SCE optimization algorithm and Simultaneous Thermal Analysis (STA) data to quantify hysteresis effects and enhance the kinetic characterization of Na2S. This approach aims to improve our understanding of Na2S kinetics, facilitating the advancement of TCES systems and further research into energy storage technologies.

METHODOLOGY

The hydration-dehydration reaction mechanism of Na2S, bridging its hemihydrate and pentahydrate forms, is a critical area of investigation for optimizing TCES systems. The multi-step reaction involves a sequence of intermediate states which collectively underpin the overall (de)hydration process. The kinetics of this multi-step reaction are represented by a series of single step reaction rate equations.
In order to characterize this multi-step reaction, the overall reaction rate for the Na2S hydration-dehydration cycle is measured using STA over a range of temperature and humidity conditions. This data is used to calibrate the SCE model, in which the kinetic equations (eq. 1 for hydration, eq. 2 for dehydration) are numerically integrated to simulate the reaction under equivalent temperature and humidity conditions as the experimental setup. The mean square error between the model and the measurement conversion is minimized for the calibration. The model delineates two intermediate states for Na2S transitioning between its 0.5 and 5 hydrate phases. In total, this results in a complex system of 32 unknown parameters, which would be difficult and laborious to determine analytically. The kinetic models used are:

$$\frac{d\alpha_n}{dt} = k_r(\alpha_{n-1})^q exp\left(-\frac{E_a}{RT}\right)\left(\frac{p}{p_{eq}} - m\right)^n \quad \text{(eq. 1)}$$

$$\frac{d\alpha_n}{dt} = k_r(\alpha_{n+1})^q exp\left(-\frac{E_a}{RT}\right)\left(\frac{p_{eq}}{p} - m\right)^n \quad \text{(eq. 2)}$$

with α the molar fraction of hydrate n, R the ideal gas constant, T the temperature, p_{eq} the equilibrium water vapor pressure of the reaction, and p the water vapor pressure. k, q, E_a, m, and n are the free parameters for calibrating the model.

RESULTS

Figure 1 presents the algorithmically calibrated model's conversion alongside those derived from STA measurements. Overall, good agreement is found between the model and the measurements during hydration. During dehydration, more significant deviations from the measurements can be observed, although it still follows the trend quite well. Since the error was minimized, deviations are likely caused by inaccuracies in the structure of the kinetic models of eq. 1 and eq. 2.

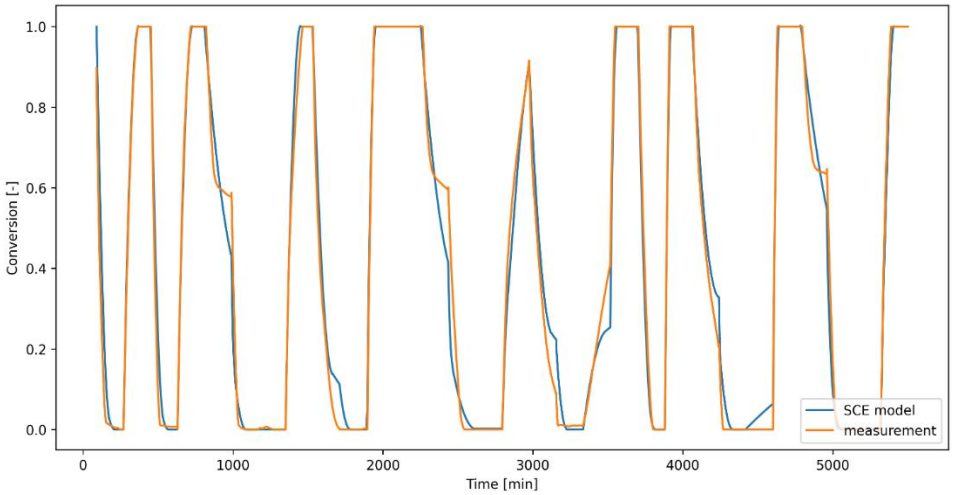

Fig. 1: Temporal conversion comparison of the STA measurements with model predictions. Temperature and pressure conditions are changed every 180 minutes. The temperature and vapor pressure ranges are 50-60 °C and 2-12 mbar, respectively.

CONCLUSION

The SCE optimization algorithm has demonstrated its effectiveness in navigating the complex, multivariate kinetics of Na2S, offering a streamlined alternative to traditional isoconversional methods that struggle with limited data scenarios. This study has highlighted the importance of integrating an appropriate kinetic model for calibration purposes, as the predictive quality of SCE is contingent upon the physical phenomena accurately represented in the model. While SCE provides a robust framework for characterizing TCES materials, the accuracy of its predictions is fundamentally tied to the underlying physics captured by the model. Moving forward, further refinement of the kinetic models is essential to fully leverage the potential of SCE in enhancing the design and functionality of sustainable TCES systems.

CONFERENCE TOPIC

Emerging heat and cold storage

ACKNOWLEDGEMENTS

This work was co-financed by TKI- Energy through the allowance scheme of the Top Sector Alliance for Knowledge and Innovation (TKI) of the Ministry of Economic Affairs and Climate Policy. Ir. Tim Rutten and Arne Sinnema are gratefully acknowledged for valuable discussions on experimental methods.

ENERGY WITH SPIRIT DATABASE. USER-GENERATED CONTENT TO SUPPORT ENERGY TRANSITION

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BASELINE

The climate crisis highlights numerous challenges at the global, national, and local level. In response to this, the European Green Deal was formulated in 2019 by the European Commission. As a new growth strategy and transformative process, the Green Deal aims to facilitate the European Union and its member states' transition towards a fair society with a resource-efficient and competitive economy (European Parliament; European Council, 2018/2001). The European Green Deal, introduced by the European Commission in December 2019, is a comprehensive policy framework aimed at making Europe climate-neutral by 2050. It encompasses various initiatives to accelerate the transition to a sustainable and low-carbon economy. Energy communities align closely with the objectives of the European Green Deal by fostering renewable energy deployment, energy efficiency, and citizen engagement. The European Green Deal acknowledges the importance of energy communities as a key pillar in the transition to cleaner energy systems. It aims to facilitate the establishment and operation of energy communities across Europe through supportive policy measures, regulatory frameworks, and financial instruments. The overarching goal is to democratise the energy sector, empower local communities, and ensure a fair and inclusive energy transition. The Renewable Expansion Act (EAG Package) represents the implementation and execution of the European Green Deal and was passed by the Austrian National Council in 2021 (Republik Österreich, 2022). One of its goals is to transition Austria's electricity supply to 100% renewable energy sources by 2030. This law amendment allows individuals to collaborate across property boundaries to collectively produce, store, consume, and sell energy. The Renewable Expansion Act serves as the legal framework for energy communities in Austria.

A LIGHTHOUSE PROJECT

To involve and actively engage vulnerable population groups in the energy transition, a consortium of 11 project partners from the business, scientific, research, and Protestant Church and its social welfare organisations came together for the project "Energy WITH Spirit. Pioneering implementation of a solidarity energy community in the Protestant Church Community Action sector in Austria." The project is led by B-NK GmbH Office for Sustainable Competence and involves the following organizations: AEE INTEC, akaryon GmbH, Diakonie Bildung gem. GmbH, Diakonie Eine Welt gem. GmbH, Diakonie Flüchtlingsdienst gem. GmbH, Dipl.-Ing. Ralf Dopheide e.U., Evangelische Superintendentur A.B. Wien, Evangelisches Haus Hadersdorf Wobes, Schülerheim Bad Goisern GmbH, and TRIGONplan Planning and Consulting Company for Landscape Ecology and Technical Environmental Protection. The three-year project started on March 1, 2023, and is funded by the Austrian Climate and Energy Fund under the "Lighthouses for Resilient Cities 2040" programme.
The project aims to ensure that the energy generated by the photovoltaic system not only meets the needs of the on-site facilities but also contributes to the well-being of socially disadvantaged and impoverished households, as well as individuals who rely on basic supplies and those who fall into the category of in-work poverty. This will be achieved through a solidarity-based approach, where approximately 10% of the energy produced in kilowatt-hours or 10% of the generated profit in euros will be allocated to these vulnerable groups. To address these objectives, first of all technical aspects, such as the implementation of smart metres, photovoltaic systems, and storage solutions, as well as different models for an optimised mix of different members and load profiles have to be examined. In addition, economic considerations will be considered, including billing methods and the

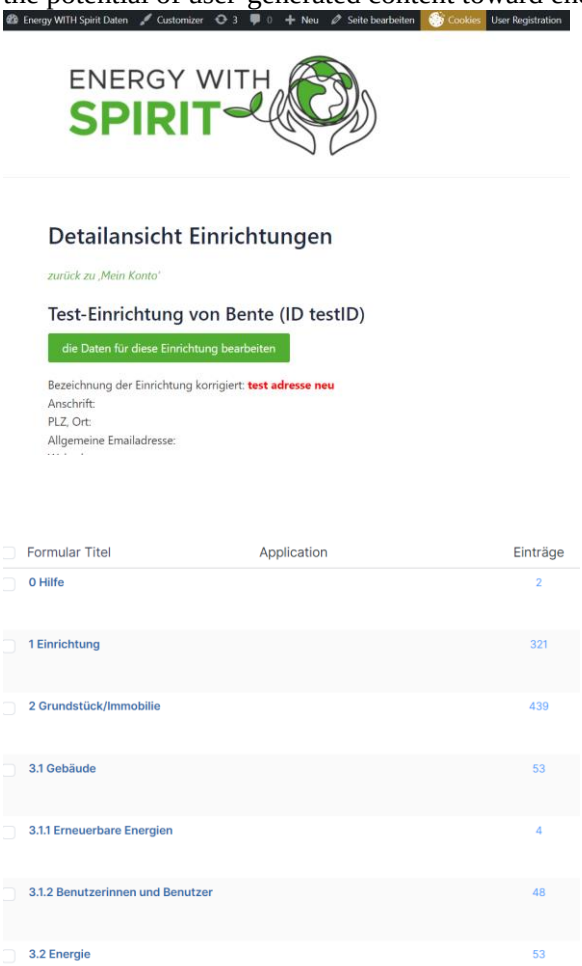
implementation of digital invoicing systems. Organisational aspects, such as verifying the income and expenditure of households and selecting recipients for energy quotas, will also be carefully managed. By tackling these technical, economic, and organisational challenges, the project seeks to ensure that the benefits of the photovoltaic system extend beyond the immediate facilities and positively impact the lives of those in need, fostering a sense of solidarity within the community.

THE "ENERGY WITH SPIRIT" REAL-ESTATE DATABASE

To assess the potential for a rollout within the Protestant community, beyond the two frontrunners in the Energy WITH Spirit project, namely the Protestant Boarding School Bad Goisern and the Protestant Secondary School Donaustadt, Vienna, a survey is currently conducted among Protestant institutions, congregations, organisations, and associations. The survey addresses the following questions:

- What is the real estate inventory in Protestant institutions, and what are the potential factors related to photovoltaic installations (locations, climate factors, etc.) (= potential prosumers)?
- Where, and in what form, could solidarity energy communities be best established?
- Who could be additional prosumers of the energy community? Who could be additional consumers?

However, for the successful dissemination of the project, a detailed recording of relevant current state parameters of the potentially suitable properties in the Protestant church community is essential. This includes a database of its technical characteristics, equipment, and energy needs, as well as socio-structural input parameters within the framework of church and political communities. Within the project, a comprehensive database has been developed. At the conference, we would like to present the underlying concepts of the database and to discuss the potential of user-generated content toward energy transition.



TECHNO-ECONOMIC COMPARISON OF DIFFERENT SOLAR-HEAT SYSTEMS AT SOUTH AFRICAN BEVERAGE PLANTS

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SUMMARY

With ongoing real-term reductions in the cost of renewable energy technologies, opportunities to reduce carbon emissions within industry has improved. While the South African industrial sector has been investing into photovoltaics to meet electricity requirements, little has been done to replace fossil fuels used for the generation of process heat, representing two-thirds of the energy consumed. While previous studies have demonstrated the benefits and limitations of solar thermal (ST) energy solutions for industrial applications, recent developments in high temperature heat pumps (HTHP) offer opportunities for novel configurations including the use of renewable energy like photovoltaics (PV). This study compares the techno-economic benefits of solar thermal energy systems with and without HTHP within the South African beverage sector. After a general consideration, simulation calculations are presented for selected applications. The cost of heat is determined for solutions ranging from PV-heat pump systems leveraging waste heat to solar thermal energy system operating on a stand-alone basis. The study calls for a coordinated effort to bring about the manufacturing and installation management capabilities to accelerate developments of solar thermal collectors and high-temperature heat pumps for industrial application where steam boilers are widely used.

INTRODUCTION

South Africa's mature beverage sector, with large production facilities, depends mainly on coal, gas and heavy fuel oil to meet process heat requirements. Beverage plants typically use steam (160-180 °C at 4-8 bars) as the primary process heat working fluid, although the majority of processes like cleaning, washing and sterilisation, usually require temperatures below 80°C. A previous study demonstrated that solar thermal projects would be viable alternatives to heavy fuel oil, diesel, gas, and even coal - should the cost of coal remain above US$250 /tonne (2020 real-term values). While steam boilers using fossil fuels are expected to continue to be the norm, it was demonstrated that up to half of fossil fuel consumption could be displaced by solar thermal collectors at reasonable costs using parabolic trough collectors. [1]
Photovoltaic installations have become increasingly attractive as a renewable energy source in South Africa in order to decrease the dependency on the public electricity grid [2]. While important to beverage operations, electricity represents approximately 40% of the total energy requirements. To meet the more important thermal energy requirement, heat pumps powered by low-cost photovoltaic energy, could be another alternative.

METHODOLOGY AND RESULTS

High temperature heat pumps can nowadays provide temperatures that are high enough for steam applications. Typical heat sources for heat pumps are surrounding air, geothermal energy stored in the ground, or nearby sources of water or waste heat from a factory. It is well known that the coefficient of performance (COP) of a heat pump strongly depends on the required supply temperature T_{sink} and the heat source temperature T_{source}.

$$COP = \frac{Q_{th}}{W_{el}} = \eta_{COP} \cdot \frac{T_{sink}}{T_{sink} - T_{source}} \quad \text{(eq. 1)}$$

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Due to the high process temperatures (120-180°C) a high source temperature is desirable, which is why inexpensive waste heat (60-100°C) should be used as heat source. Typical COPs are in the range of 2.0-4.7 [3,4]. Ambient air or geothermal energy could be used for lower sink temperatures in case of integration at process level. ST or PVT could also be used for elevated source temperatures.

In this paper different configurations of ST, PV and HTHP are studied, simulated and evaluated in terms of economics and CO_2 reduction. For a solar thermal heating system the optimal LCOH can be obtained by varying storage capacity for a given field size, as shown in figure 1. One possible configuration with heat pump and PV is shown in figure 2.

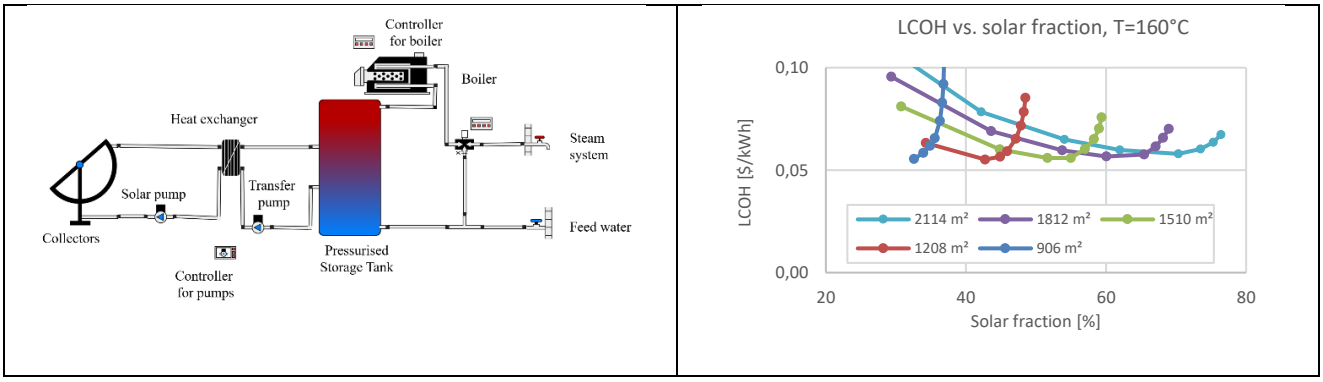

Fig. 1: Process schematic with ST (left) and LCOH vs solar fraction and aperture area in Cape Town [1] (right)

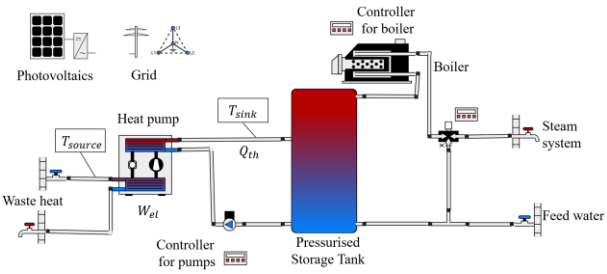

Fig. 2: Process schematic example in Polysun with PV and HTHP

Chances and risks of lowering the steam pressure and temperature are discussed, since, from a thermodynamic viewpoint, lower temperatures would increase the solar thermal efficiency and the heat pump COP. Another issue is the discussion of integration on process level rather than on supply level.

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CONFERENCE TOPIC

"Renewable heating and cooling, including high temperature applications" or
"Approaches towards net-zero/negative emissions in the industry including CCU"

SCENARIO-BASED COMPARISON OF SUSTAINABLE HEATING AND COOLING SYSTEMS FOR PIGLET PRODUCTION SYSTEMS

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SUMMARY

Highly industrialised pig farming is energy-intensive due to the sensitivity of highly-bred pig breeds, making efficient production only feasible in optimal climatic housing conditions. To reduce CO2-emissions, it is essential to utilise heating and cooling supply with maximum efficiency and renewable share. However, with regulatory requirements in a state of constant flux and changes in market demand, pig farmers must enhance their pig production practices, ultimately impacting the efficiency of existing heating and cooling supply concept. As a first step, a case study was conducted on a large piglet farm to develop a methodology for predicting annual heating and cooling load profiles. The methodology can be used for other farms with similar boundary conditions. The prediction of heating and cooling load profiles offers a crucial starting point for comparing potential heating and cooling systems in terms of energy usage, economic efficiency, and CO2-emissions. The comparison centers on the heating systems biogas and heat pump and the cooling systems compression chiller and absorption chiller.

Keywords: Heating demand, Cooling demand, Pig farming, Pig housing, Piglet production systems

INTRODUCTION

Constant adaptation and further development of piglet production systems are necessary in today's world as market demands change and legal requirements increase. In order to maintain market share, pig farmers must react to volatile conditions, potentially requiring structural changes to pig housing that can impact the number of animal places and therefore increase heat demand. Optimising the housing climate by employing cooling measures during the summer months can improve production efficiency and animal wellbeing. Both the structural changes to pig housing and optimisation of housing conditions impact the heating demand and create a necessity for more efficient cooling. Additionally, the upcoming discontinuation of subsidies for many of Germany's 9,600 biogas plants also affects will also affect pig farmers, requiring a reevaluation and analysis of the current heat supply system. (BMEL 2023). For these reasons, the comparison focuses on the biogas and heat pump heating systems and the compression and absorption chiller systems for cooling. To make this comparison effectively, it is essential as a first step to predict heating and cooling load profiles for a piglet farm. For this purpose, a methodology is developed to determine future heating and cooling load profiles for different scenarios based on current heat demand and house climate data measured in a piglet production system. The prediction of heating and cooling load profiles provides the vital foundation for comparing potential heating and cooling systems in terms of energy usage, economic efficiency, and CO2 emissions. Pig production can be divided into two stages: piglet production and pig fattening. Within the piglet production system, heat demand accounts for 87% of the total energy demand. In pig fattening , heat demand has a share of 66% (Seifert et al. 2009). The focus of the methodology and the comparison is exclusively on intensive pig production systems with an emphasis on piglet production. Conversely, pig fattening processes are not considered.

PIG PRODUCTION SYSTEM AND REQUIREMENTS OF INDOOR ENVIRONMENT IN PIG HOUSING SYSTEMS

The sow's gestation period lasts between 112 and 115 days. The weaned piglets stay with the sow for 21 to 28 days and are nursed by her. Following weaning, the piglets are relocated to the piglet housing for approximately five weeks. When they reach a weight of 30 kg, they are transferred from the piglet to the fattening housing. Depending on the process stage and age of the piglets, varying conditions are suitable for optimal animal performance. Table 1 illustrates the performance-driven optimal temperatures. The piglet production/rearing phase lasts approximately 170 days and with up to 32 °C as shown in Table 1, making it a significant driver of heat demand in the pig production value chain (Giner Santonja et al. 2017). These optimal air temperatures are the main reason for heating and cooling demand within the housing.

Tab. 1: Optimal air temperature in pig housing (DIN 18910 2017)

Pig Housing	**Optimal air temperature of the stable air [°C]**
Mating and gestating sows	20 to 16
Farrowing sows	20 to 16
Weaners	32 to 20
Piglets	30 to 20

The heating is currently provided by underfloor heating or wall radiators and heat lamps in piglet nests. If the housing has a cooling system, high-pressure evaporative cooling is the main method used. Additionally, ventilation systems are used during summer months to maximize the air volume flow and protect the pigs from heat stress. During the winter months, there may be a decrease in air flow, but it remains crucial to remove harmful gases. Nevertheless, this exchange of air results in significant loss of heat.

CASE STUDY

The case study is located in Thüringen, Germany and involves 5,000 sows and 160,000 piglets, with an annual heat demand of 5 GWh and an annual electricity demand of 2.6 GWh. From the measured heat flow and housing climate data of the studied piglet production unit, heating and cooling load profiles are generated. These profiles will serve as the basis for evaluating and comparing the heating and cooling systems. Figure 1 displays the heating, cooling, and electricity demand of the investigated piglet farm, alongside the electricity and heat generation of the CHP unit.

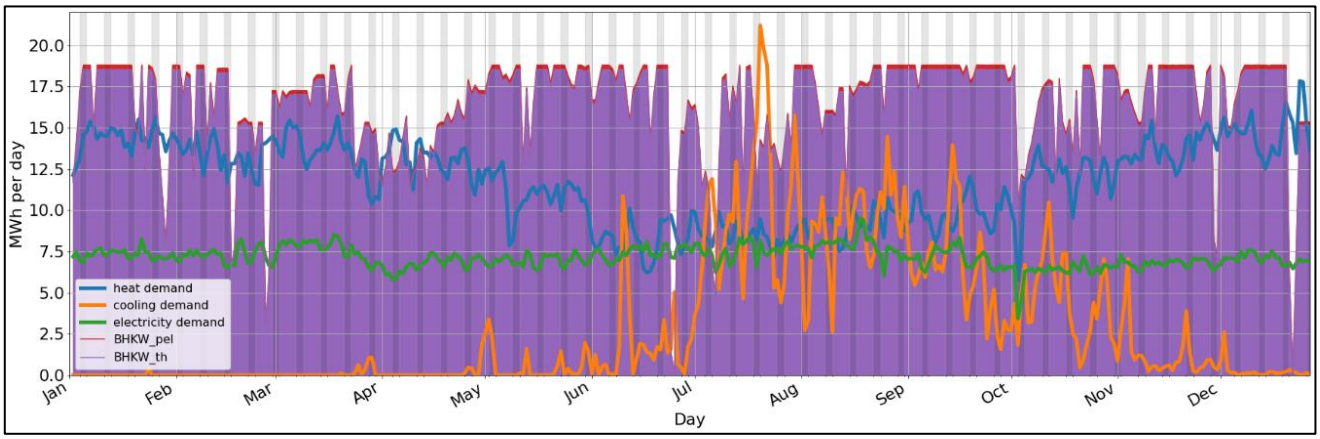

Fig. 1: Comparison of annual heating, cooling, and electricity demand of investigated piglet farm with daily electricity and heat production of CHP unit in 2021

METHODOLGY

Figure 1 illustrates that heating and cooling demand occur simultaneously and must, therefore, be generated concurrently. To ensure this, an integrated heat pump can be used as an alternative to a CHP system with a chiller. When both heat and cooling generation are utilized, the integrated heat pump has the advantage of higher efficiency. Therefore, the study compares and assesses the heating and cooling systems with and without subsidies to determine if the heat pump is a feasible substitute for the biogas plant. It also examines the influence of cooling systems on energy consumption, costs, and CO2-emissions, and identifies which cooling system is best for the biogas plant. The heating and cooling systems studied consist of a combination of different technologies from the categories listed below:

- Category heat production: Biogas CHP, Heat pump
- Category electricity production: Biogas CHP, Photovoltaic System from 1.9 MW_p to 2.5 MW_p
- Category subsidies for electricity feed-in: subsides, no subsides
- Category heat storage: Heat storage from 10 m^3 to 100.000 m^3
- Category cooling: Compression chiller, absorption chiller
- Category heat recovery: Air scrubber with heat recovery, heat recovery of pig manure

The Figure 2 displays the intricate nature and range of energy systems that undergo evaluation and comparison. To assess potential heating and cooling systems in terms of energy usage, economic efficiency, and CO2 emissions, key figures were identified. This key figures for the comparison of heating and cooling systems provides insight into the overall environmental and economic impact. Energy usage is evaluated based on the secondary energy demand, while the economic efficiency compares the determined Levelized Cost of Electricity (LCOE) and Levelized Cost of Heat (LCOH), as well as the overall energy costs. To enable emission comparisons, the CO2 factor is calculated per kilowatt hour (kWh) generated.

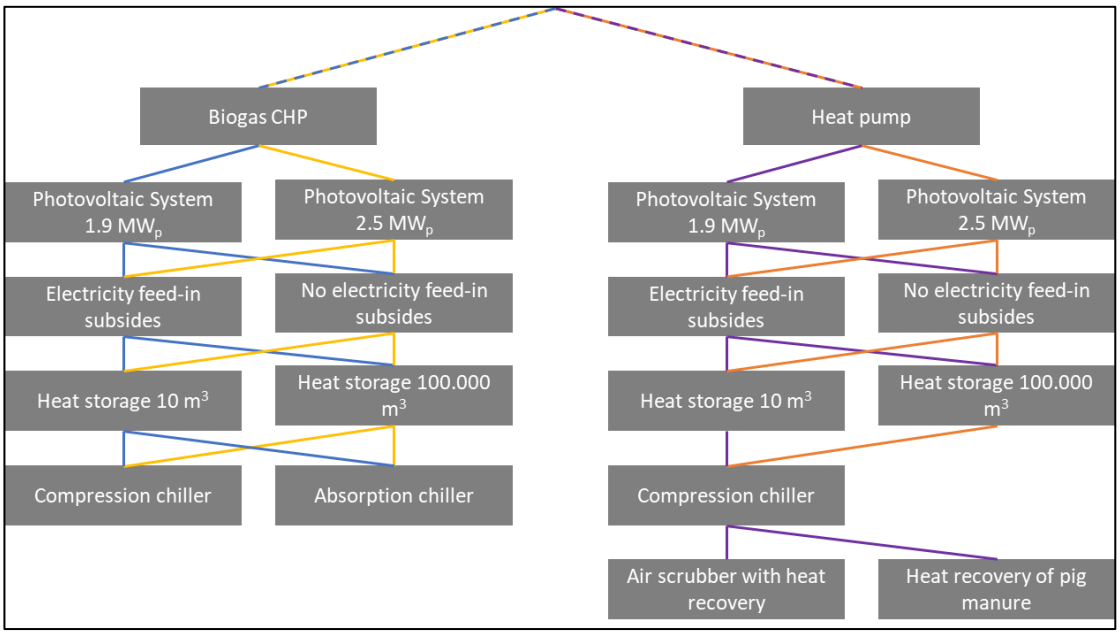

Fig. 2: Energy systems that undergo evaluation and comparison

OUTLOOK

Considering multiple heating and cooling supply options provides the advantage of anticipating future changes based on various load profiles. This enables the selection of the most energy-efficient and cost-effective concept for the farm being analysed. Detailed planning must take into account the specific conditions of the site of operation. The full paper presents the methodology used to create heating and cooling load profiles and to

evaluate the heating and cooling systems for a piglet farm, focusing on energy consumption, economic efficiency, and CO2-emissions.

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CONFERENCE TOPIC

The abstract refers to the following Conference Topics:

- Renewable heating and cooling, including high temperature applications
- Solutions for Energy Efficiency

EXERGO-ECONOMIC EVALUATION OF LIBR-H2O ABSORPTION HEAT EXCHANGER PROCESSES FOR DISTRICT HEATING APPLICATION

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SUMMARY

In Austria, district heating networks supplying towns, districts and buildings are already helping to reduce CO_2 emissions by making local heating systems unnecessary. This paper aims at upgrading and expanding this supply system by replacing the heat-exchanging substation with the novel "exergy transformer" device, which makes use of an absorption technology for covering seasonally varying needs of heating and air conditioning. The core process of the systems is a thermally driven, innovative absorption process, from which heat as well as heat and cold (as a coupling product) or only cold (for air conditioning) can be decoupled on the secondary side. Extensive thermodynamic simulations, selection procedures for variants and plausibility considerations are carried out to verify this concept and plant engineering aspects are taken into account. Furthermore, an exergo-economic analysis, including a bi-objective optimization, is carried out to evaluate the individual systems.

INTRODUCTION

Motivation and State of the Art

A sustainable and green future requires the use of renewable, clean and green energy, but we must be aware that fossil fuels still play a decisive role in the areas of heat supply through to personal and public mobility. Kranzl et al. [1] state, that approx. 33 % of the energy used in Austria is used for the provision of space heating and that this is responsible for a share of approx. 20 % of total Austrian CO_2 emissions. Fossil fuels are still used to a large extent (around 60 %) in the provision of heating. This also includes fossil electricity and district heating generation. The Report "Faktencheck Energiewende 2018/19" (Fact check energy transition 2018/19) by the Klima- und Energiefonds [2] took a closer look at the heating transition in particular. And the dependence of the heating sector on fossil fuels shows that an energy transition and the achievement of the targets in the Paris Climate Agreement are linked to the successful management of the heating transition and the associated phase-out of fossil fuels. This also necessitates the call for innovative solutions in heat supply systems such as district heating. While in 1980 there were just 83,000 homes in Austria with a local or district heating connection, this number had already risen up to 1,091,000 by 2021. If this number is converted into a percentage, this results in the fact that in 2021 almost a third (27.2%) of all homes in Austria were connected to a district heating network and were primarily heated by it. [3]

With the use of a thermally driven process, the so-called "exergy transformers" are intended to upgrade and expand district heating by replacing the heat-exchanging area or house transfer stations with these innovative systems, which are intended to cover not only the seasonally varying demand for heating, but also for air conditioning. The core process of the systems is a thermally driven, innovative absorption process, from which heat as well as heat and cold (as a coupling product) or only cold (for air conditioning) can be decoupled on the secondary side. The developments and application of the absorption technology and their applications in the field of district heating can also be seen in the examples of Cudok et al. [4], which describe the current state of the art with regard to the use and field of application of absorption heat transformers. Similarly, Donnellan et al. [5] provide a comprehensive overview of research in the field of heat transformers over the last two decades. The focus is on optimization studies, alternative cycle configurations, comparisons of working fluids and case studies of industrial applications. Sun et al. [6] describe a novel waste heat district heating system with a combined heat

and power system based on ejector heat exchangers and absorption heat pumps. This should enable the energy consumption of existing CHP plants to be reduced by recovering waste heat from the exhaust steam of the steam turbine, and also increase the heat transfer capacity of the primary district heating network by lowering the return temperature. Mirl et al. [7] investigated the integration of an absorption heat pump with the working fluid pair ammonia-water into a district heating network in order to achieve a thermal drive of the circuit by lowering the return temperature. Arabkoohsar and Sadi [8] investigated the use of an absorption chiller with parabolic trough collectors (PTC) for the joint supply of district heating and cooling for a case study in Denmark. In detail, an absorption chiller of a hospital, which is supplied by the local district heating and heavily loads the district heating network, was analysed and with the system, the district heating network is less loaded and the excess heat is used for the local district heating network.

Method and Materials

A total of three absorption models, are modelled, calculated, optimized and analysed. Figure 1 shows an example of an exergy transformer based on an absorption circuit for the extraction of heat for the secondary grid.

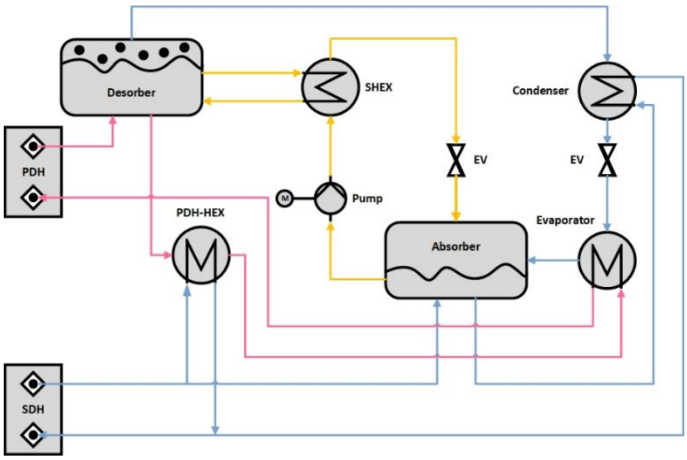

Fig. 1: Exergy transformer based on an absorption circuit for the extraction of heat for the secondary district heating grid (SDH)

This model shows the usage of the heat at a temperature level of about 140 °C from the primary district heating network (PDH), to power the absorption process (LiBr-H_2O as working fluid) and to serve heat at temperature level of about 65 °C/50 °C for the usage in the secondary grid. The techno-economic modelling consists of two analyses. The first one is the so-called "first law analysis" and is characterized through a steady-state analysis of the plant, which is used for the investigations. This approach neglects all time-dependent variables, which leads to a vast simplification of the simulation model. Nevertheless, basic knowledge about the boundary conditions as well as information about the thermodynamic relationships of the individual components is required to obtain a valid process model. The second one is the "second law analysis" and serves to identify thermodynamic inefficiencies. Indicators necessary for this are, for example, the exergy efficiency $\eta_{ex,tot}$. The exergy efficiency is defined by the so-called product exergy E_P and the exergy of the resource (fuel) E_F. The term E_P describes the exergy of the product generated by the system (cooling, heating), while E_F serves as a hypernym for all applied resource exergy needed to generate that product (heat source and auxiliary power for pumps etc.). To ensure an optimal system design, information on exergy efficiency alone is often not sufficient. Therefore, in addition to the efficiency evaluations, another assessment criterion is established that represents the economic aspects of the system. This methodology is also known as techno-economic analysis and subsequently leads to a bi-objective optimization problem in which not only the exergy efficiency is to be maximized, but also the costs are to be minimized.

Outcomes

Figure 2 shows the results of the bi-objective optimisation in terms of the Pareto front (left) and the corresponding parameter space (right). The exergy efficiency $\eta_{ex,tot}$ and the system costs $\dot{C}_{tot}$ were declared as objective functions. The graph on the left shows, that there is an almost linear relationship between the system costs and the exergetic efficiency. The bottom left point represents the optimal scenario when the exergy efficiency is the only objective function (lowest $\dot{C}_{tot}$), while the top right leads to the optimal design when the total system cost is the only objective function (highest $\eta_{ex,tot}$). The ideal solution for the bi-objective optimisation would be a point at the bottom right, as both objective functions have their optimal values, i.e. highest exergy efficiency and lowest total cost rate. The graph on the right shows, that the system costs $\dot{C}_{tot}$ increase approximately linearly with the degassing width $\Delta\xi_E$, whereby the exergetic efficiency also increases with this increase. The primary district heating temperature $T_{PDH,in}$ changes only slightly during optimisation, as a higher temperature leads to better results.

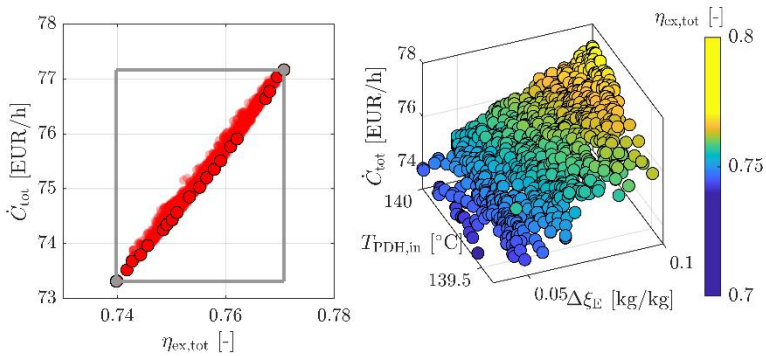

Fig. 2: Left: Pareto set of solutions optimised according to exergy efficiency and system costs. Right: Parameter space of Pareto set

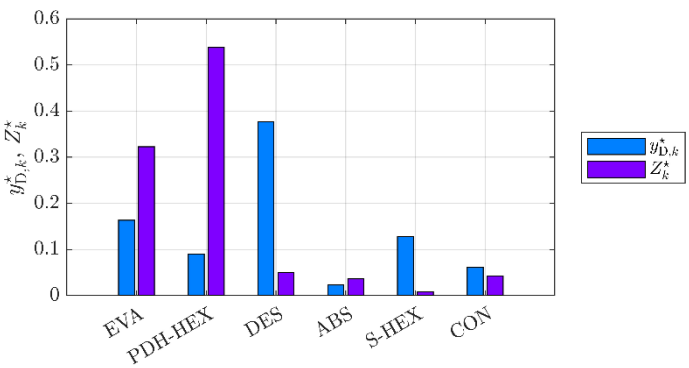

Fig. 3: Exergy destruction rate and the relative investment costs of the main components.

Figure 3 shows that the primary heat exchanger (PDH-HEX) causes high relative investment costs Z_k^* due to the large heat exchanger area (approx. 44 m²). In comparison, the absorber (ABS) shows that the relative investment costs are lower, as the heat exchanger area is smaller (approx. 19 m²). In terms of exergy destruction, the desorber is responsible for the highest exergy destruction rate $y_{D,k}^*$ compared to all components.

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CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Future District Heating and Cooling Technologies

ACKNOWLEDGEMENTS & CONTACT

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BTTAB – BROAD-BASED TESTING OF ENERGY-EFFICIENT DEMONSTRATION BUILDINGS WITH THERMALLY ACTIVATED BUILDING COMPONENTS

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SUMMARY

Buildings with thermally activated building structures (TABS) from Austria with different building uses and technology applications are subjected to monitoring, which includes operating data as well as the experiences of participants and users. The aim of this study is to take a general look at the various applications of the thermal building component activation technology and to evaluate and compare the demonstration buildings with the help of suitable evaluation criteria.

INTRODUCTION

The expansion of renewable energy generation as well as extensive possibilities for energy storage are central cornerstones of the energy transition. Thermal building component activation can be a key aspect here, as it can be used multifunctionally as a heating and cooling delivery system and as a storage system for fluctuating renewables. These applications not only offer enormous potential for the integration of renewable energies and waste heat, but they also promise high economic attractiveness and impress with their simplicity in implementation, operation and use.

In order to investigate these properties of TABS on real buildings, in the study BTTAB (Becke et al. 2023) 18 demonstration buildings spread over Austria have been selected for monitoring and surveys. It is intended to provide information about the performance of the storage and energy flexibility potential on the one hand, and to generate essential findings with regard to user comfort, user satisfaction, economic aspects in construction and operation as well as functionality on the other.

METHODOLOGY: ENERGY AND COMFORT MONITORING, USER AND STAKEHOLDER SURVEY

At the beginning, information about the building services systems and any existing measuring and metering equipment of the 18 demonstration buildings was obtained and the modalities of the provision of measurement data were clarified.
In the next step, based on the experiences of the project partners AEE Intec and e7, a detailed monitoring concept was created to answer the relevant aspects regarding energy generation, heat and cold output and storage via TABS and comfort in reference rooms. In addition, a simplified measurement procedure was developed, tested and subsequently applied to all demonstration buildings for the quick and cost-effective determination of the operative temperature in reference rooms (essential comfort criterion).
Complementary to the energy and comfort monitoring, a user questionnaire was developed to query and analyse the subjective satisfaction of the building users, which is applied to the 18 demonstration buildings. Targeted surveys of stakeholders (investors, planners, executors) complete the creation of a comprehensive and well-founded knowledge base.

MONITORING RESULTS AND COMPARISON OF THE APPLIED TABS

The demonstration buildings differ not only in their type of use, but also in the application of TABS in combination with the energy supply concept. In the ongoing work of the BTTAB study, the differences are highlighted and contrasted with the monitoring results. The applied TABS technologies are classified according to the following distinguishing features: Activated components and installation type of TABS, use for heating and/or cooling, type of control strategy of TABS.
Findings already obtained from energy and operational monitoring as well as statements on the use of storage potential are presented and contextualised with the building structure, use and energy generation system. The results from the comfort monitoring of reference rooms are presented clearly. Likewise, the results from the simplified measurement procedure for determining the operative temperature of reference rooms are presented and compared with the results from the comfort measurement according to ISO 7730.

Although the monitoring of some demonstration buildings is still ongoing and the surveys have not yet been finalised, many results can already be provided that are highly relevant for the planning, design and operation of future buildings with TABS.
The following statements can be made in general:

- TABS examined are well-functioning systems
- The users feel very comfortable in these buildings
- TABS offer optimal conditions for the use of renewables, such as optimal temperature levels for heating and cooling, reduced peak loads compared to other available delivery systems in combination with a high storage capacity.
- In order to make the best possible use of the storage potential of TABS, more elaborated control strategies must be introduced.

MONITORING AS AN INSTRUMENT OF QUALITY ASSURANCE AND KNOWLEDGE GENERATION

The project BTTAB illustrates that monitoring is highly relevant for innovative buildings with new technologies such as TABS. The monitoring of energy and comfort parameters proves to be an ideal instrument for monitoring the control operation of buildings, the individual technologies used and the interaction of complex plant structures. Monitoring makes it possible to assign the energy consumption to specific control settings of individual components or to specific user behaviour, to quickly locate faults and, if necessary, to counteract them with measures in the system operation or user behaviour. The effectiveness of implemented measures can also be quickly verified with the monitoring system at system level. The aim of energy and comfort monitoring is to continuously improve technical building operation and comfort conditions, to become more resource-efficient and to pass on the knowledge gained for future building projects.

ACKNOWLEDGEMENTS

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The knowledge gained is disseminated to international stakeholders through active participation in the technology collaboration programme IEA ES Task 43 - Standardized use of building mass as storage for renewables and grid flexibility. Further details under: https://iea-es.org/task-43/

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CONFERENCE TOPIC

Emerging heat and cold storage

RENVELOPE – A DEMONSTRATION OF SUSTAINABLE SERIAL RENOVATION

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SUMMARY

Renvelope develops and demonstrates multi-functional, prefabricated and energy-efficient building shells for serial and energy active refurbishment. This abstract gives an insight in how the Renvelope shell will pave the way towards serial-manufacturing of facades and roofs, both of which can house renewable energy sources, heating and cooling systems, ventilation systems in addition to insulation. Their functional characteristics for thermal stability, improved air-quality, and reduced energy losses all contribute to CO_2-reduction, which is a key driver in today's development sector. An entire shell can be installed non-invasively in a matter of days thus significantly reducing touch-time on the building site. The presented research findings are based on one of the three ongoing real-scale demonstrations of the technology in Austria and focuses on the serial renovation of a residential building in Vienna.

INTRODUCTION

Austria has committed to being climate neutral by 2040 [1]. The building sector represents a key challenge for the phase-out of fossil fuels and is responsible for around a third of Austria's total energy demand [2]. The Renvelope project is a flagship project that will demonstrate the developed Renvelope-shell on three different building typologies: a multi-story residential building in Vienna (urban environment), an office building, and an educational institution. The seventeen project partners represent research, development, and construction industry, as well as property owners, thus offering the project direct access to a wealth of information for the development of Renvelope-shells across the entirety of the affected value chain.

MULTI-STOREY RESIDENTIAL DEMONSTRATOR

One demonstrator of the Renvelope project is a residential building in Vienna owned by the Sozialbau AG (Austria's largest social housing company). It was chosen as a demonstrator because it is representative of many buildings not just in Vienna or Austria but also in the rest of Europe, due to its poor efficiency rating, its dependency on fossil fuels and the necessity to renovate non-invasively. The building (dating from the 70s) is situated in a typical urban environment, with attached neighbouring houses on two sides, and bordering directly onto the pavement. It has an L-shape footprint and features a small courtyard. The building contains 24 separate units, which are all reliant on decentral gas boilers for heating and domestic hot water. There is no insulation on the external walls, the roof space or on the cellar ceiling.

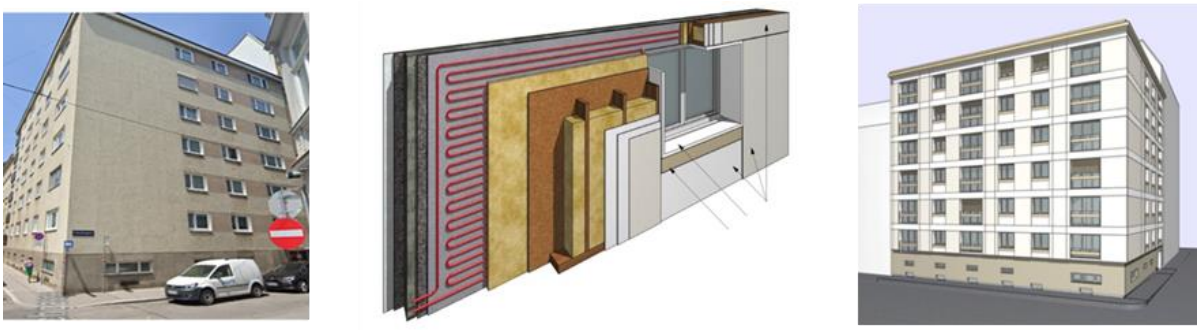

Figure 40: Original demonstration building (left), facade layers of the RENVELOPE shell (middle), Rendering of the demonstration building after refurbishment (right). Sources: Google street view, Nussmüller Architekten

The challenges associated with this (and generally this type of) building have different dimensions and need to be tackled by RENVELOPE, as outlined in Table 1.

Table 4: Challenges for serial and energy active refurbishment for different dimensions

Challenges	Most relevant
Local	Different seasonal requirements (heating & cooling); Minimal space for geothermal probes and solar conversion technologies in urban landscapes.
Social	No permission to enter apartments (during any of the planning or construction stages); Construction time must be kept to a minimum (continuous usage of building), necessity to ensure high acceptance rates
Engineering	Effective integration of renewable energy sources, reducing CO_2 emission and energy demand by 80 %, Integration of technologies that are not yet designed for plug&play, Height of building (six storeys) poses challenges for fire safety and no-scaffolding construction method.
Data	Information deficiency and missing interfaces, Lack of digital data,No clear path for rapid renovation planning cycles across partners.
Architectural	Allow for architectural freedom despite constraints set by the demands of façade-integrated technologies.
Economical	The costs of the Renvelope-shell must be competitive to the costs of conventional thermal renovation of a façade and roof.

During the renovation, the residential building will be fitted with an architecturally pleasing façade with an underlying wooden beam construction. A 25 cm layer of insulation will be integrated into the elements and underneath them (in contact with the integral wall) will be water-bearing pipe-system with an innovative design to effectively transmit heat or cold to the integral wall. It fulfills the function of a conventional wall heating element, however from the outside of the original building. With this set-up a large thermal mass is activated (heated or cooled) ensuring high thermal stability and personal comfort. The energy source for heating and cooling is a heat pump with boreholes located in the courtyard. Domestic hot water will be prepared by a central air-source heat pump in the roof space and distributed to the individual units through disused chimneys. The asbestos-containing roof tiles will be replaced to allow for the weight of a photovoltaic (PV) system.
The main benefits of the renovation for this demonstrator are the following:

- Up-front digital planning and serial production leading to shorter construction times and non-invasive renovation processes, and ensuring high-quality and long levity of façade elements;
- High comfort level is ensured though thermal activation of all exterior walls, floors and ceilings;
- Renewable energy sources are effectively integrated and efficiently used for domestic hot water, heating and cooling and electricity consumption;
- At least 80 % reduction in CO_2 emissions and energy demand;
- Estimated costs of the renovation after the initial planning stage is 1000 €/m² (Gross Floor Area).

CONCLUSION

All partners of Renvelope have set out with the goal to develop and demonstrate a multi-functional, prefabricated and energy-efficient building shell. At this point all plans for the implementation have been finalised for a residential building in Vienna. The two particularly important needs of this residential building are to step away from a fossil-based heating system and to improve its thermal efficiency. The planned Renvelope-shell together with the air- and ground-source heat pumps will provide solutions to both these needs.

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CONFERENCE TOPICS

Renewable heating and cooling; Solutions for Energy Efficiency; Sustainable Renovation

DIGITALIZATION OF URBAN ENERGY SYSTEMS – A USE CASE DRIVEN DESIGN APPROACH OF A DATA EXCHANGE PLATFORM TO INCENTIVIZE ENERGY DATA SHARING

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SUMMARY

Within the DIGICITIES project, a data exchange architecture is established to facilitate the use of urban energy data for advancing the urban energy system transformation along the digital value chain and between the key stakeholders. Recent observations show that the current digitalization of energy system is lacking behind the requirements resulting from various domains of energy planning, management and data driven services like digital twins. Key challenges are availability, transparency, security and privacy issues encountered by collecting and sharing energy data, particularly at city and district scale. Besides, they are often not represented in standardized formats to facilitate their exchange and utilization among diverse city stakeholders. The conceptualized data exchange platform (DEP) applies a use case driven approach reflecting the need owners' requirements. In Co-creation with city stakeholders in Austria and Switzerland several use cases are selected to define the required functionality of the DEP to support cities in achieving their energy and climate goals.

ABSTRACT

The European transition strategies consider the digital and green transitions as interlinked as highlighted in the notion of "Twin Transitions" -Towards a green and digital future- where digitalization is considered to hold substantial potential for supporting the European clean energy transition at different levels. In fact, digitalization contributes to accelerate the green transition by generating and exposing real-time data that -in the case of energy systems- helps advancing various domains including enhancement of energy saving, effective integration of renewable energies, making smarter decision to optimize energy system performance and above all providing a solid basis to improve the quality of energy systems modelling. In this regard the advancement of digital platforms that store energy data in structured and integrated ways within one place can help managing the increasing complexity of energy systems.

Within the European ERA-Net SES project DIGICITIES, a multi-layer data exchange platform (DEP) is being developed to facilitate the use of urban energy data and advancing the urban energy system transformation along the digital value chain. The DEP is designed to cover the various steps of data collection, structuring, cleaning, processing and provision to the support the need of city stakeholders in various areas of urban energy systems like energy planning and digital twins. Besides, it addresses the challenges related to data availability,

transparency, security and privacy encountered along the digital value chains. The established DEP is being verified by a set of use cases established in co-creation with local city stakeholders in Austria and Switzerland.

The intensive literature review reveals a clear lack of standardized data availability and quality of data required for energy system applications, in particularly energy system modelling. To close this gap, the applicability of the proposed platform is envisioned to be demonstrated for both energy management and energy modeling, including the application of a digital twin.

This contribution focuses on the specification of the platform requirements based on a set of use cases that encompass building energy monitoring, digital twins, and control optimization, while also considering data privacy and security. First, the exercise of data analysis and cleaning of the available monitoring data serves to derive common requirements on data quality and generalizable data cleaning procedures. Second, a concept to represent measured data and simulated data in linked data ontologies is outlined to maximize the benefit of the gathered data for different stakeholders. The semantic linking between data on different levels is conceived to incentivize data sharing and to support the advancement of urban energy system modeling by providing a customized methodology to process data from different sources and make them available following commonly agreed standards.

As depicted in Fig. 1 the DEP covers the steps of data collection, transfer, cleaning, processing, evaluation, storing and provisioning for further applications. It is flexibly configured to meet the needs of various potential applications and use cases. This entails handling various categories of open source data and use case specific data including monitoring data from lighthouse city projects to serve several applications for diverse city need owners.

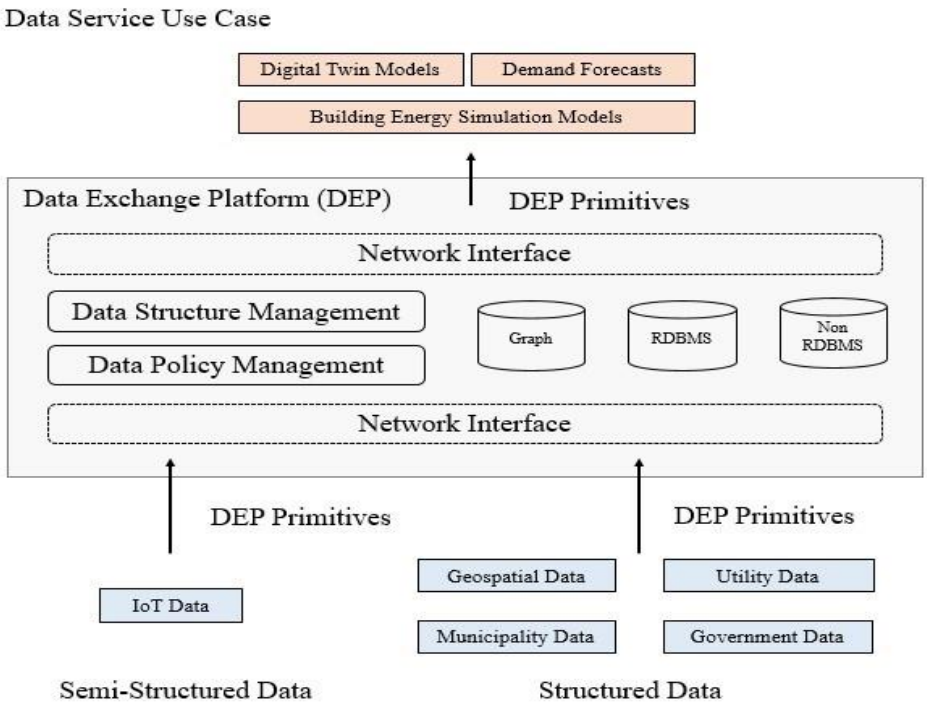

Fig. 41: Conceived platform architecture overview

Based on the ongoing implementation of the Austrian use cases, requirements regarding cleaning of monitoring data are specified. Further, it is intended to demonstrate for the proposed platform to manage data flows to increase the value of the available data and to allow for data-based decision making.

Moreover, to harness the platform's full potential, the DEP must be standardized, requiring data providers to adhere to standardized practices, as cross cutting applications such as urban energy system modeling, require public and private entities to share data on commonly agreed terms. Therefore, the conceived DEP is designed to

benefit such need-owners and use cases. In addition, the standardized collecting, processing and structuring allows for standardized analysis tools to be applied and developed.

Looking ahead, the DEP will be implemented to demonstrate its applicability in supporting different use cases such as:

1. Model predictive control of a Zero Energy Building
2. Optimization of battery operation to increase self-consumption
3. Hydro-electric power plant operation for demand shifting
4. Municipal energy planning
5. Long-term urban energy demand forecasting
6. Quality check and cleaning of monitoring data

The above-mentioned use cases are intended to cover a wide range of applications, including data privacy issues and a demonstration of handling various data sources. However, the use case driven design approach is not complete, and the platform design is being improved as the project evolves and requirements emerge.

CONFERENCE TOPIC

Digitalization for Future Energy Systems
Coupling of Energy Sectors

REVIEW OF POSITIVE ENERGY DISTRICTS: DILEMMAS AND OPPORTUNITIES

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SUMMARY

In 2018, EU launched the programme "Positive energy districts and neighbourhoods for sustainable urban development" with an aim to support the planning, deployment and replication of 100 Positive energy districts (PEDs) by 2025. This is an ambitious target considering the various challenges on implementing PEDs. This paper provides an overview of the state-of the art knowledge on the various aspects related to PED with a specific focus on definition, relevance of regional contexts, energy efficiency, energy production and energy flexibility. This review provides an insight on areas for further research to facilitate the widespread implementation of PEDs. Further, the experiences on PED case studies from existing literature will also be presented.
Keywords: energy transition, energy efficiency, renewable energy, cities

INTRODUCTION

Cities have large potentials for supporting sustainability and combating challenges such as climate change, environmental degradation and health issues. Moreover, literature suggests that districts and neighbourhoods within cities hold significant possibilities for change (Magrini et al., 2020) to reduce energy and greenhouse gas emissions. In a study by Nematchoua (2021), the potential for urban, rural, and sustainable neighborhoods to mitigate GHG emissions and energy consumption were investigated. They found that the amount of GHG emitted by neighborhoods could be reduced with 53-97% by 2050, and that rural neighborhoods, with substantial building renovations/energy efficiency measures and PV production potential in the area, can reach carbon neutrality by 2050. Districts also have several advantages for energy solutions compared to buildings, such as energy exchange between buildings, community storage, better renewable energy (RE) production potential, and other possibilities to reduce the energy input and use (Sabine et al., 2021). Recently the focus has expanded from individual houses to seeking possibilities of city districts and neighborhoods (Magrini et al., 2020). In the following sections a few of the PED aspects are briefly discussed and it will be expanded in the full-article.

PED definition

Implementation of large urban scale projects on sustainability requires huge resources and investments. Subsequently the focus has been towards smaller areas within the city, such as districts, with a shorter time frame (Erba and Pagliano, 2021). Positive energy district is defined in the white paper as ".. energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy" (JPI Urban Europe., 2020a), which can be considered as an "initial definition" for PED (Vandevyvere et al., 2019). In addition to the energy issues, the PED definition includes other objectives such as social concerns, inclusiveness, solutions to energy poverty, district wide considerations on the transportation networks and design optimization (Hedman et al., 2021). Nevertheless, there is still no common universally accepted definition for PEDs (Derkenbaeva, 2022).

As per a study that interviewed a few Swedish professionals, who have experience in PED projects, the "positive energy" and "annual surplus" terminologies in the PED definition may be unsuitable for Swedish conditions and a few interviewees were of the opinion to have a shorter timeframe (Mattsson at al., 2023). However, it is still uncertain which timeframes are ideal and it also requires knowledge on how a shorter time frames will affect the project such as sizing of the infrastructure, land use and magnitude of local RE production

(Mattsson et al., 2023). A key finding from the interviews is the importance of a local perspective and the need to consider each city's preconditions such as seasonal variations, mismatch of produced energy/demand, size of districts, legal barriers, isolated islands (Mattsson et al., 2023).
The lack of a standard and consolidated definition for the PED concept is considered as one of the main limitations for PED development and deployment in European cities (Zhang et al., 2021). IEA EBC-Annex 83-Positive energy districts (2020-2024) is developing a definition for PED, technologies and planning tools https://annex83.iea-ebc.org. Energy production, energy efficiency and energy flexibility are the three pillars that form the basis for the general PED framework, and the optimal balance between the three pillars is central in planning a PED.

Renewable energy production

In PEDs, RE production within the district is encouraged, and if energy needs to be imported then RES is prioritized. Weather conditions is one of the major factors that influence energy consumption of the building stock (Jepsen et al., 2022), and areas in or near the Arctic circle have a higher energy demand than other areas, due to the cold and harsh climate (Yurui et al., 2019), along with other challenges. The seasonal variation of available solar energy is larger in northern Europe, and there is a mismatch due to the larger energy demand during winters. Energy efficient retrofitting is critical to achieve PED with colder climates and denser population (Bruck et al., 2022a). Rehman et al (2022) in their study showed that it is difficult to reach positive energy buildings in urban areas in Nordic climate if all buildings' energy demand is included. They suggest that in such situations the investment cost in the energy system would be 47-62% of the LCC, and the rest is operational cost. As per Bruck et al (2022b), the districts in southern Europe (closer to equator) is positive for the economic viability of PED projects. On the other hand, districts that are already connected with district heating (DH) may have a significantly higher cost (Bruck et al., 2022a) to become PED. This is partly attributed to lower operating cost and also lower GHG emission from DH system as compared to the individual fossil fuel boilers.

Energy Efficiency

Energy efficiency is another requirement for PED projects, and should ensure that the renewable energy used in the district is efficiently used and not unnecessary exploited and wasted. Nevertheless, the reference framework based on national consultations (Reference Framework for Positive Energy Districts and Neighbourhoods) suggests to give energy efficiency priority as the space needed for RE generation is limited, especially in urban areas (Derkenbaeva, 2022).

Energy Flexibility

Annex 67 defines the energy flexibility of a building as "the ability to manage its demand and generation according to local climate conditions, user needs, and energy network requirements" (Jensen et al., 2017). A study by Erba and Pagliano (2021) in buildings in Milan suggest that the concept of sufficiency and efficiency and flexibility need to considered together to have a realistic chance to achieve PED. Realization of positive energy districts is expected to significantly increase the share of RE in the electricity system. As per a study by Huber et al (2014), the flexibility requirement of power systems would increase dramatically when the combined share of wind and solar power generation become greater than 30% of the annual electricity consumption. The requirement for flexibility would be less for geographically large, transnational power systems.

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CONFERENCE TOPIC

Solutions for Energy Efficiency

PRODUCTIVE USE OF SOLAR ENERGY - TECHNO-ECONOMIC ASSESSMENT OF A PINEAPPLE DRYING PILOT IN UGANDA

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SUMMARY

Agriculture is a key sector of the Ugandan economy and beyond. 80% of the working population in Uganda is dependent on agriculture for their livelihood. The demand for agricultural products is growing rapidly, but the sector is characterized by low productivity and limited technologization. Affordable and reliable renewable energy is therefore key to foster sustainable development in the country.
Together with local partners, a turn key system solution for the agri-food sector was developed and implemented. Food processing technology and solar energy know-how is transferred and adapted to the local needs in the community. The technology has proven capacity to improve the entire value chain starting from certified organic agriculture, food processing technology, solar energy supplies up to product sales.
A small batch pilot plant has been established in Kangulumira, Uganda primarily focusing on drying of pineapples. The project combines solar heat, photovoltaic, optimized food processing and quality management. The pilot plant was implemented and is in operation since May 2023. First techno-economic results as well as social impact analyses show the proof of concept and the base for replicability, scalability of the concept to other agri-food sectors and countries with similar needs.

Keywords: solar food conservation; stand-alone solution; farm2fork; techno-economic Analysis

INTRODUCTION

High food losses in agricultural production in the global South account for up to 39% of all food produced worldwide and 8-10 per cent of global greenhouse gas emissions each year (Lipinski 2022). The global agri-food system consumes around 30% of the world's energy production, mainly in the form of fossil fuels. On the other hand, many small farms in the global South still do not have access to affordable and clean energy (IRENA & FAO 2021). Smallholder agriculture is the backbone of agriculture and food security as well as a major source of employment in many countries of the Global South, which is limited largely by insufficient technical support and sales opportunities. (Rauch et al. 2020).

In Uganda many smallholder farmers lack the expertise and access to modern food processing technology. Rural areas are characterised by inadequate infrastructure in the areas of transport, electricity and water. However, electricity is a basic requirement for the use of modern food processing technologies which makes sustainable commercial processing very costly. In addition, relatively high initial investments are required to procure modern food processing technologies which shrinks farmers' the profit margin for the sale of finished products even further.

PILOT AND FIRST RESULTS

TWIGA Sun Fruits takes a holistic farm2fork approach and takes together with its Ugandan partners a responsibility for the entire value chain, from organic farming, production and energy supply to import and distribution in Europe. With a view of the entire value chain, an integrated system solution for drying organic pineapples was developed.

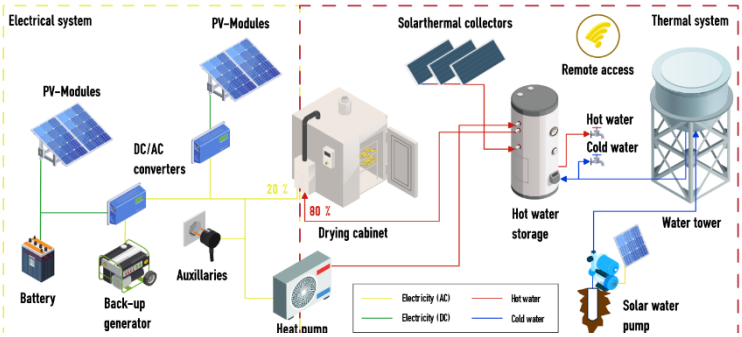

Fig. 1: technical layout of the pilot plant in Uganda

Technical wise the project includes solar heat and PV supply with a micro-grid, optimized food processing and a small manufactory where highest hygienic standards are complied with. The pilot plant was implemented and is in operation since May 2023.

Fig. 2: areal shot of the plant in Kamira, Uganda

The demo plant serves as a proof of concept for the reliable and economic application of solar for process heat and of PV for auxiliary demands. With the successful demonstration of the concept, further developments and scalability will be advanced. Interested Stakeholders in applying the system concept represent agricultural sectors like coffee, tea, grain, dairy, fish and fruits.

The basis for replicability are well-trained local partners who will install and maintain the plants. The implementation and developments are further accompanied by scientific partners in selected local research institutes. In future, the concept will further be extended to solar cooling and can be used in any agri-food processing industry.

The concept, data monitoring on technical performance, economic modelling of the business case, a social impact analysis and lessons learned will be presented in detail.

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CONFERENCE TOPIC

Renewable Heating and Cooling including high temperature applications, Life Cycle Assessment, Finance and Business Models

PACKED-BED HEAT STORAGE USING LIQUID METALS AS HEAT TRANSFER FLUIDS

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SUMMARY

As the share of fluctuating renewable energy sources is growing, the utilization of energy storage systems is becoming increasingly crucial to bridge the gap between energy supply and demand in order to maintain a reliable energy supply. Among the energy storage solutions that are currently investigated, thermal energy storage stands out as a rather simple, cost-effective and efficient, especially if the energy is later on required in the form of heat. For the high-temperature applications such as process heat supply for high-temperature industrial processes, there is ongoing research on storage concepts, configurations, and materials. This contribution will show the current status of the ongoing research at the Karlsruhe Liquid Metal Laboratory (KALLA) that focusses on the use of liquid metals as heat transfer fluids in sensible packed-bed heat storage systems.

Keywords: heat storage, packed bed, liquid metal, heat transfer, lead bismuth

INTRODUCTION

Liquid metals offer a wide liquid state temperature range (ca. 100°C to 1000°C) and excellent heat transfer rates because of their high thermal conductivities, which is more than an order of magnitude larger than that of conventional fluids such as molten salts, oils or gases (Lorenzin and Abánades, 2016). Therefore, apparatuses can be built with smaller heat transfer areas transferring the same amount of heat, being thus, more cost-efficient. This effect is also utilized for the thermal energy storage concept. Here, a packed bed stores the thermal energy and the liquid metal transfers the heat to and from the solid particles. In order to demonstrate such a storage system on a pilot-scale, first, a lab-scale storage system was built and tested to derive important design parameters (Müller-Trefzer et al., 2022). As liquid metal, a eutectic mixture of lead and bismuth (LBE) was used with a melting point of ~125°C. Based on the gained results, a pilot-scale demonstrator was designed and built to be integrated in an existing liquid metal loop at KALLA. In parallel, material (storage material and structural material) and component tests (e.g. pumps, valves, measurement equipment) are conducted at temperatures >600°C to determine and test compatible materials for the use of liquid metals at elevated temperatures.

LAB-SCALE PROOF OF CONCEPT

In the literature, packed-bed heat storage systems using liquid metal as heat transfer fluid have only been investigated numerically yet (Bozorg et al., 2023). Therefore, a lab-scale experiment called VESPA has been built and operated at KALLA to prove this concept for the first time, to test measurement equipment and to derive parameters for a pilot-scale demonstrator (Müller-Trefzer et al., 2022). The test rig is shown in Fig. 1 (left). Different filler material candidates were tested upfront in stagnant liquid lead at 500°C with the result that the zirconium silicate was compatible and thus, selected for the lab-scale heat storage. Further details on the filler material screening procedure and results can be found in the publication by Müller-Trefzer et al., 2023. The charging (at 380°C), discharging (at 180°C) and standby behaviour of the packed-bed heat storage with a porosity of 37% was then investigated in 36 cycles. The influence of different parameters on the vertical temperature profile in the 1-kWh heat storage was investigated. When comparing the results of a liquid metal-only heat storage with the packed bed solution, both an improved separation of the cold and hot part in the heat storage and an

increased capacity were achieved. Within the measurement range of the lab-scale system, a higher mass flow lead to improved stratification in the packed-bed storage.

PILOT-SCALE DEMONSTRATOR

Currently, the integration of a pilot-scale (100 kWh) heat storage in one of our liquid metal loops at KALLA is underway. A 3D drawing of the test rig including the heat storage is shown in Fig. 1 (right). As filler material, zirconium silicate (ca. 1.5 tons) is again used, as it was proven successfully in the lab-scale pre-tests. The heat storage will be operated between ca. 180°C (discharging) and ca. 450°C (discharging) due to the melting temperature of the LBE at the lower end and the temperature restrictions of the liquid metal loop materials, sealings and instrumentations at the upper end. In parallel, we conduct extensive material and component evaluations, including pumps and valves, to ensure compatibility with liquid metals for temperatures (>600°C).

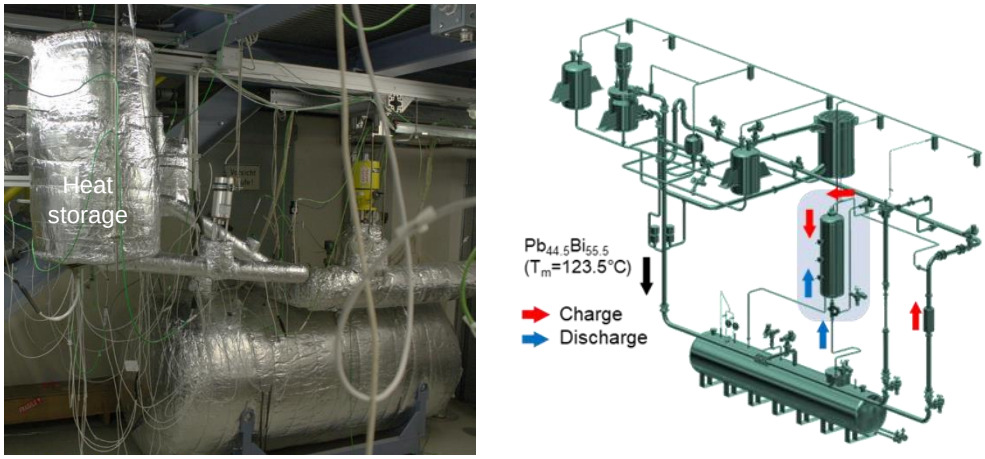

Fig. 1: Left: photo of VESPA test rig (photo: Dieterle/KIT); right: pilot-scale demonstrator integrated in the largest liquid metal loop at KALLA

CONCLUSIONS

The use of liquid metals as heat transfer media offers benefits such as superior heat transfer efficiency and elevated operating temperatures. However, one significant challenge is compatibility of materials at high temperatures (>600°C). Consequently, our research focusses both on demonstrating heat storage systems, progressing from laboratory testing to pilot-scale implementation and on material development, the latter in close cooperation with KIT-IHM (A. Weisenburger and colleagues).

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications; Emerging heat and cold storage; Coupling of Energy Sectors; Flexibility and Stability of Thermal and Electric Grids

ANALYSIS OF THE POTENTIAL OF THE ENERGY SUPPLY WITH A PYROLYSIS PLANT

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SUMMARY

For the smallest district of the German city of Freiburg nine different scenarios for an energy supply based on market available pyrolysis plants as alternative to the current wood chip boiler were investigated. Two options turned out to be potentially more economical and ecological as the reference system. Decisive for the economics are the thermal and electrical performance of the pyrolysis plants, their biochar production rate, and the availability of local biomass waste. A maximum of negative emissions of around 1260 tons CO2 every year is achievable (compared to current emissions of approximately 280 tons).

INTRODUCTION

To achieve the goals of the Paris agreement it is not enough to only cut CO2 emissions to net-zero. Moreover, it is inevitable to use and expand negative emission technologies to capture CO2 from the atmosphere. To reach the goal of limiting the temperature rising until 2100 to 1.5 °C, more than 800 gigatons of CO2 must be removed from the atmosphere. (Rockström et al. 2017; Werner et al. 2018)

Pyrogenic carbon capture and storage (PyCCS) is a negative emission technology that allows to actively remove carbon from the atmosphere and to store it for long term by following few process steps. In the first step plants remove CO2 from the atmosphere to build biomass. In the next step the biomass gets pyrolyzed, so the biomass converts into biochar, bio-oil and pyrogas. In the last step the biochar and bio-oil are processed in a way that it cannot oxidize and release the containing carbon back to the atmosphere. This can be done by using the biochar for soil improvement or if the products get worked into concrete. The carbon content of biochar typically has values between 75 % and 85 %. (Schmidt et al. 2018) A carbon content of 80 % means that 1 ton of biochar contains the carbon of more than 2.9 tons CO2.

Right now, there are already market available technologies for pyrolysis plants. These plants convert biomass and gain pyrogas, which can be energetically used. The biochar is produced as a side product and can be sold. Even though most pyrolysis plants are only built for heat supply, some can also provide electricity and heat. Differences between the technologies mostly come from the biomass that the pyrolysis plants are able to convert and the ratios of pyrogas and biochar produced. Most of the pyrolysis plants operate with wood chips as input biomass. Some plants can also use a mix of different kinds of biomasses.

For this investigation the option of replacing a wood chip boiler as base load heat supply for a small district heating network by a pyrolysis plant was analyzed under energetical, economic and ecological aspects in one heating period (from October to inclusively April). In the district there is an animal park located that produces big amounts of organic matter from agriculture and animal husbandry. That biomass is currently not used and could potentially be used in a pyrolysis plant. Furthermore, another municipal enterprise which operates two greenhouses, a restaurant for park visitors and five residential buildings belong to the district. The current energy supply of the district network consists of a wood chip boiler combined with a peak load oil boiler for heat supply and electricity purchase from the electrical grid. This is the reference system for the investigated scenarios.

METHODOLOGY

An assessment tool developed in MS Excel carries out calculations based on the heat and electricity demand of the district for various pyrolysis plants available on the market, as well as the reference system. As the heat demand of most buildings was not known, load profiles were generated by a building model according to ISO 52016-1 as input for the calculations. To determine whether energy supply with a pyrolysis plant instead of a wood chip boiler makes sense, the results of the calculations were used. The economic calculation is based on the VDI 2067. Both costs and the emissions were calculated for the total energy supply with heat and electricity during the heating period. The selection of the pyrolysis plants was based on the relevance of the manufacturers on the market and the availability of information. Furthermore, different technologies should be mapped, to identify potential advantages and disadvantages. Technical specification or prices were either requested and taken from the manufacturers website or derived from other pyrolysis plants.

As the provided biomass of the farm is a versatile mix of wood, green waste and animal manure, the input biomass for the pyrolysis plants was differentiated into the biomass mix or just the wood content, since most pyrolysis plants and the wood chip boiler only operate with wood. If pyrolysis plants need more biomass than provided by the farm, additional biomass must be purchased as wood chips. Surpluses of produced heat and electricity get dissipated to the environment and fed into the electrical grid.

RESULTS

For the economic viability of the plants, it was possible to show the dependence on the amount of biomass produced by the farm that can be used for pyrolysis. This reduces the amount of wood chips that must be purchased and lowers the demand-related costs. Especially plants that can use the full biomass mix of the farm prove to be useful, since the wood content of the farm is very low (~ 6 % wt.) compared to the rest of the organic matter. In addition, it has been shown that biochar, which is a by-product during pyrolysis, generates important revenues. Therefore, a high biochar production is not only reasonable regarding emissions, but also has a positive effect on the operating costs of a plant. Finally, a dependence of the electrical power could be worked out for the economic efficiency. The output of a plant ideally is just as big as the power required by the district. Plants that produce more electricity than required are less economic since they cause high investment costs and have to feed electricity into the grid at low prices.

The emissions also depend on the thermal and electrical output of the individual pyrolysis plants. Pyrolysis plants with a high degree of coverage in heat cause less emissions generated by the peak load boiler. Plants with a high degree of coverage in electricity result in lower emissions due to purchase of grid electricity. Biochar production also has a major influence on emissions, as these generate negative emissions. From the results of the emission calculation for the total energy supply, the plant configurations with the highest biochar production have the lowest emissions. Supply concepts in which the pyrolysis plant has a high degree of coverage of the heat and power supply and at the same time has a high biochar production are the most advantageous in terms of emissions. Nevertheless, all the investigated supply concepts with a pyrolysis plant result in far lower CO2 emissions than the current supply with the wood chip boiler and purchase of grid electricity.

The calculations show that two supply systems with a pyrolysis plant cause lower life cycle costs than the reference supply system with a wood chip boiler. The system with the PX1500 plant has lower costs than the reference system both with and without the extension of the ORC-module if they are operated with a biomass mix. In this case, 61.7% of the required biomass for pyrolysis can be covered from own production. At this point, the wood chip boiler can already cover 11.2 % of its fuel demand from own biomass production by only using the wood content. The supply system with the PX1500 pyrolysis plant with the extension of an ORC-module performed the best in most of the studies. The plant can provide 98 % of the required heat and 97 % of the required electricity during the heating period. With a thermal output of 510 kW and the electrical output of 90 kW, it is in a range that is well suited to the small district, and thus produces relatively little surplus heat and electricity. In particular, the ability to utilize the full biomass mix of the farm, ensures that the plant can be

operated at the lowest costs. At the same time, the plant has a high biochar production which causes high negative emissions. In one year, the plant can save over 1500 tons of CO2 in one year compared to the wood chip boiler with almost 54.900 € lower operating costs per year.
In general, the energy supply with pyrolysis plants can be a reasonable alternative to conventional concepts, but the economics must be proved for any individual case. Especially for large consumers with a high demand for heat and electricity, a pyrolysis plant can be a suitable concept, since all the energy generated is used. Also, an application that has no break during summer could provide significantly better results.

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CONFERENCE TOPIC

Approaches towards net-zero/negative emissions in the industry including CCU

COMBINED INVESTMENT AND OPERATIONAL OPTIMIZATION OF POWER-TO-FUEL PLANTS AT CLOSED COAL POWER PLANT SITES

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SUMMARY

As part of the RFCS GreenDEALCO_2 project [1], this study explores repurposing decommissioned coal power plants as power-to-fuel facilities. From an economic perspective, a comprehensive approach is proposed to optimize the investment and operation of power-to-fuel plants at retired coal power plant sites. The study identifies reusable assets and evaluates the best available technologies. PEM Electrolyzer and Post-combustion carbon capture technologies are selected consequently. The study investigates power-to-methanol at a decommissioned coal power plant near a potential CO_2 source. Moreover, the piece-wise linearization technique is used to model the part-load efficiency curve for the PEM electrolyzer, which significantly impacted the optimal size and operation of the power-to-methanol plant compared to linear efficiency. The electrolyzer operation at 20-40% during high electricity prices reduces total electricity consumption and hydrogen storage investment cost.

INTRODUCTION

The shift from coal power plants to curb CO_2 emissions is prompting a global move towards greener energy sources. This transition offers opportunities to repurpose old infrastructures for new technologies [2]. There's an opportunity to integrate E-fuel production into these facilities in the context of EU regulations affecting coal power plants. The existing infrastructure, such as water treatment stations, and transportation networks, can support green hydrogen and e-fuel production and transport. Connections to the electrical and gas grids can reduce costs and facilitate the integration of produced green hydrogen. The heat generated can be used in district heating or within the process while existing storage areas can hold hydrogen and other products. Components like water demineralization units are essential for producing ultrapure water for electrolysis, and steam production installations can be repurposed for district heating systems. The power-to-fuel concept offers a way to store energy and help decarbonize air travel and heavy transportation. While there are some demo projects showcasing this technology, its commercial viability is currently limited by a better understanding of the process interactions. This paper addresses these challenges by discussing the effects of part-load efficiencies of PEM electrolyzer, and hydrogen storage sizing and operation on the overall investment and operational optimization of power-to-methanol plants which addresses a significant research gap [2].

METHODOLOGY

At first, the modelling approach and the best available technologies were determined. Subsequently, use case and scenarios were identified. Afterwards, the optimization model was set up using oemof [3]. The mathematical approach adopted is linear and mixed-integer linear programming. The components of the power-to-fuel system, such as the PEM electrolyzer, hydrogen storage, methanol synthesis, etc., were modelled using in-built oemof components. Input parameters, constraints, assumptions, and boundary conditions are also determined at this step using available literature [4, 5]. The part-load efficiency curve for the PEM electrolyzer described in [6] is linearized using a piece-wise linear approach. The electricity price curve considered for all the scenarios is taken from [7]. The optimization model utilizes the Gurobi solver with specific settings such as configuring solver-specific options including handling non-convex problems and setting a MIP gap tolerance of 5%.

RESULTS

The size and operation of power-to-fuel system highly depends on the amount of CO_2 that should be utilized, desired fuel output and maximum hydrogen production capacity per hour. The size of hydrogen storage tends to be larger for higher electrolyzer capacities and higher desired fuel output. For the best economic output, the electrolyzer operates more on 20-40% part-load reducing the electricity consumption leading to smaller hydrogen storage investment which has a significant impact on the levelized cost of methanol produced as a result. This signifies the importance of combined design and operational optimization approach.

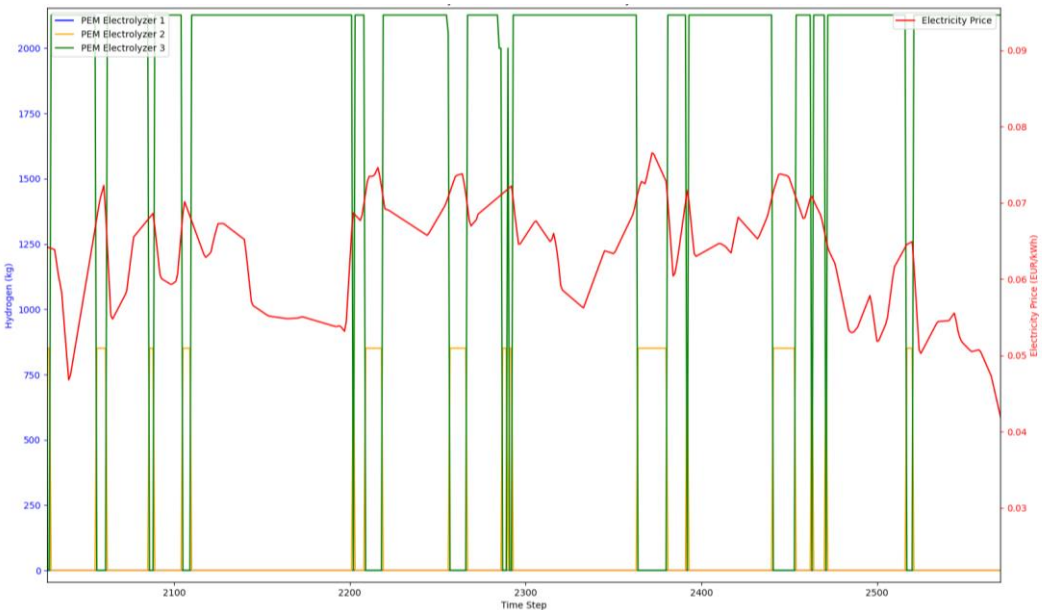

Figure 42: Part-load behavior of electrolyzer w.r.t. electricity prices

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CONFERENCE TOPIC

Approaches towards net-zero/negative emissions in the industry including CCU

AGENT BASED MODELLING AIDED ENERGY COMMUNITY DESIGN: A CASE STUDY IN AUSTRIAN CONTEXT

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SUMMARY

In response to the digital shift in energy systems, this study employs Agent-Based Modelling (ABM) to simulate complex dynamics within energy communities (ECs). Utilizing Building Energy Modelling (BEM) and Urban Building Energy Modelling (UBEM), we forecast building performance to define energy load profiles. Our focus revolves around optimizing pricing in various business models, emphasizing its pivotal role in bridging economic interests. Drawing from real-world configurations like Gneis, we analyze diverse energy scenarios, underlining the transformative potential of digital tools in modern energy systems.

INTRODUCTION

Digital tools and methodologies are revolutionizing the energy landscape, presenting innovative solutions to traditional challenges. At the forefront of this transformation are energy communities (ECs), driven by clean energy goals and decentralization(Standal *et al.*, 2023). However, their design, coordination, and optimization face complex challenges, stemming from varying stakeholder interests, dynamic energy flows, and fluctuating demand-supply paradigms. Governments and policymakers advocate for the aggregation and alignment of energy loads to mitigate grid pressures, underscoring the need for innovative strategies(Fioriti, Frangioni and Poli, 2021). In this context, the refinement of business models becomes crucial to amplify the adoption of ECs across Europe. Among the diverse business models available for ECs—ranging from Peer-to-Peer (P2P) markets to Power Purchase Agreements (PPAs)—this research spotlights the significance of pricing, which not only bridges economic interest of participants, but determines viability of business models (Das *et al.*, 2023).

METHODOLOGY

A multi-agent system strategy is put forth to assess variations in self-consumption and the economic benefits for both consumers and prosumers over a year, rooted in historical pricing data and simulated energy performance of the designated neighborhood. Inspiration for the model is drawn from the real-world energy configuration of Gneis, which features diverse buildings equipped with photovoltaic (PV) supply and a hydropower plant (HPP) showcased in Figure 1. An attempt is made to decode the emergent patterns across varied scenarios, which are influenced by the fluctuating number of participant groups within the EC.

Fig. 1: Gneis district showcasing the potential actors of the energy community in the neighborhood

RESULTS:

The primary objective of this model is to determine the most economically viable composition of entities for inclusion in an EC, taking emergent behaviors into account. After examining various scenarios with varying composition, options are ranked and a strategy for EC creation and expansion is suggested.

DISCUSSION:

In summation, this study delves deeply into the intricate dynamics of energy communities, emphasizing the quest to ascertain the ideal collection of prosumers and consumers with diverse load profiles. Utilizing Agent-Based Modelling, we provide insights that shed light on the composition of these communities, especially within the Austrian context. The findings highlight the importance of tailoring energy communities based on stakeholder load profiles and their reactions to pricing dynamics. This offers invaluable guidance for policymakers, energy stakeholders, and communities, directing them toward crafting more adaptive and sustainable energy ecosystems.

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CONFERENCE TOPIC

This abstract refers to the following conference topic: Digitalization for Future Energy Systems.

INTEGRATED ENERGY SOLUTIONS: A CALL FOR INCLUSION OF NON-TECHNICAL FACTORS

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SUMMARY

The central supposition put forward in this paper is that typical building-related energy efficiency measures do not automatically yield the looked-for global environmental effects. Rather, many such measures entail two kinds of reductionism, in that they *i)* treat buildings detached from the larger system (such as the urban context), to which they belong; *ii)* concentrate on solutions, which are predominantly technical in nature. As a consequence, the complexity of the challenge may be neglected, along with other non-technical, yet potentially critical areas of concern. Such areas include, inter alia, economy, politics, policy, as well as societal and psychological framework conditions. In this paper, we discuss a few typical instances of such reductionist approaches to shed light on factors that impede their utility. Moreover, we highlight a few instances of systemic methods that have been suggested to have the potential complex problems in general, and the environmental implications of energy efficiency measures in the context of the built environment.

Keywords: Energy efficiency, Buildings, Integrated solutions, Non-technical factors, Complexity

THE ENERGY PERFORMANCE GAP CASE

It has been plausibly argued that one of the most efficient measures to enhance the built environment's energy performance is to focus on the thermal retrofit projects of the existing building stock. However, such projects frequently display a phenomenon referred to as the energy performance gap, which denotes the deviation of buildings' actual post-retrofit energy performance from prior expectations as obtained through computational estimations (Mahdavi et al. 2021). One of the contributing factors to this gap has been suggested to stem from the so-called rebound effect. As applied to buildings, this effect suggests that expected energy savings from retrofit projects may not come about due to the behaviour of building users. Specifically, building occupants may use the positive monetary effect of improved energy efficiency to elevate their living quality (e.g., higher thermal comfort levels in winter due to elevated temperature settings). To fully understand and address this effect, one needs to consider not only the technological dimension of the retrofit measures, but also take those psychological and socio-economic factors that influence occupants' behaviour in buildings and their interactions with building systems.

TECHNOLOGY VERSUS LIVING MODELS

Building-related energy efficiency strategies focus typically on technical matters, related to, for example, thermal retrofit and mechanical equipment. Yet, technical factors are not always the most critical ones. To explain this point, consider a previous study of the energy-related ramifications of alternative living models at the district level, which was conducted for the city of Vienna (Austria) (Brandl et al. 2011). The motivation for this study was not a technical one but a demographic one, namely the increase in the population of elderly living alone in relatively larger dwellings. This is relevant not just because of the energy demand implications, but also in view of required spatial and financial resources. The study pursued the hypothesis that communal living models, due to higher density and jointly used spatial resources, offer not only energy-efficiency rewards (i.e., heating load reduction) comparable to comprehensive thermal retrofit measures, but also benefits in terms of space usage efficiency, as well as urban sprawl mitigation and traffic reduction.

TECHNOLOGY VERSUS URBAN SPRAWL

High HDI Countries (Human Development Index) may be advanced in terms of technology and workforce qualification, and they may have the resources for large-scale building retrofit campaigns. However, a recent global study revealed a pronounced positive correlation between the energy-wise alarming urban sprawl increase and HDI (Behnisch et al. 2022). Thereby, Europe was shown to be the continent that is both the most sprawled and also the most rapidly sprawling. In fact, almost a third of OECD countries are subject to high urban sprawl, despite a long record of land use regulations aimed at managing the growth of the built areas. This may be related to preference for low-density suburban areas, paired with the prevalence of vacant dwellings in these countries. These observations cast doubt on the assumption that formally stringent rules and regulations or high technological standards alone, and without sufficient consideration of developmental policy and integrated planning strategies, would warrant an energy-efficient mode of managing and operating built environments.

TOWARD INTEGRATIVE SOLUTIONS

The present contribution argues that the impact of building-related energy efficiency measures may be constrained, if we *a)* treat buildings as stand-alone entities and *b)* persist in an exclusively technology-centric mindset. Major breakthroughs in sustainable energy solutions targeted at the built environment cannot be achieved solely through technological instruments, but require consideration of economic boundary conditions, policy frameworks, and governance strategies. To this end, sound theoretical foundations (e.g., general system theory, complexity theory) (Bertalanffy 2015, Waldrop 1992) must be considered and formal means of integrative problem-solving (including multi-variate analysis, multi-criteria optimization, stochastic methods, agent-based modelling) must be deployed. However, the fruitful application of these theories and tools in the practice requires the sustained commitment of the responsible stakeholders, both in the public domain, and in the private sector.

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CONFERENCE TOPIC

Solutions for Energy Efficiency, Policies

OPTIMIZATION MODEL DEVELOPMENT FOR HYBRID COAL-SOLAR THERMAL PROCESS HEATING SYSTEM FOR OPAQUE BEER BREWERIES

(Case Study Bulawayo Company)

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SUMMARY

Considering economic and environmental profitability, beer brewing companies must integrate solar on coal fired boilers. Using the Bulawayo opaque beer brewing company which has a production capacity of 135 000 litres of opaque beer per day and the returns are very valuable in the city councils quest to improve service provision to the residents. Some of the products are exported to neighboring countries, bringing in the much needed revenue. Of the locally consumed beverages, 70% goes to the rural market around the city while the rest is consumed by the urban market. An energy audit and energy balance were carried out using case study results. An excel model to determine the optimum ratio for coal and solar energy was developed so as to maximise production at minimum energy costs. The optimum energy from coal was determined and a solar plant sized to provide the energy. Finally, an economic analysis was carried out to justify investment into the project. Integration was found to be justifiable and a model was designed so as to determine the optimum coal-solar balance with solar contributing 35% of the energy. The investment into the project was justified by a low payback period of 10 years 7 months given the fact that solar heating systems have a lifespan of over 25 years. The final design was also provided, taking the old design and the best permissible improvements into consideration. The capacity of the project to reduce coal usage by incorporating solar justifies the investment into this project. Solar is environmentally friendly, has a long life span, has low maintenance costs and the solar global irradiation is very high in this region, with an average of 792W/m2. The integration system finds application in all industrial and domestic setups where process heating is required. Food processing plants, beverage manufacturers and all heat absorbing production systems can integrate solar and coal so as to reduce production costs, maintenance costs, pollution and increase profitability.

ASSESSMENT OF BEST PRACTICE EXAMPLES FOR DATA CENTER INTEGRATION IN ENERGY SYSTEMS

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SUMMARY

This presentation is based on the study "Synergies between Data Centers and Energy Systems (DCESS)", which addresses the integration of Data Centers (DCs) into energy and water systems in order to achieve the European Green Deal[1] and Digital Decade[2] targets for energy efficient and climate neutral DCs by 2030. This contribution focuses on two activities within the DCESS study: Best Available Technologies (BAT) from other energy-intensive industries (EIIs) [3], which allow a better integration of these industries into energy and water systems, were evaluated for their transferability to DCs. In addition, lessons learned from case studies of DCs that are already optimally integrated with electricity, heat or water systems were collected through interviews and literature review for the benefit of the industry as a whole.

INTRODUCTION

The study, " Synergies between Data Centers and Energy Systems (DCESS[14])", is unique in that it examines the integration of DCs into energy systems, in line with the European Green Deal and Digital Decade targets for energy efficient, carbon neutral DCs by 2030. DCs are central to Europe's digital transformation, but their significant energy consumption raises environmental concerns. They are heavily dependent on cooling, which accounts for over 40% of electricity consumption[4]. The high energy demand of DCs can strain local power grids and water resources, leading to potential shortages. Integrating DCs into energy systems, using waste heat, and transitioning to renewable energy sources are essential for sustainability. Several best practice case studies are presented that aim to balance the need for digitalization and energy efficiency are presented. Efforts include returning excess energy to the grid, scheduling workloads during off-peak hours and reducing water demand. The potential of DCs to contribute to energy systems beyond mere consumption is highlighted, with innovative approaches and pilot projects across Europe.

OBJECTIVES AND SCOPE

The overarching goal of this study is to facilitate the more effective integration of DCs into energy and water systems, aligning with the ambitious Green Deal and Digital Decade targets for highly energy efficient and climate neutral DC by 2030. To ensure the success of this overarching goal, the study is structured into five sub-objectives (SOs):

- Mapping existing technical, regulatory, and environmental policies related to DC integration into energy and water systems across various governmental levels in the EU (SO1).
- Assessing barriers and opportunities through consultation with relevant official, industry, and academic sources at different governmental and geographical levels to facilitate the 2030 goal (SO2).
- Drawing comparisons with resource-intensive industries and their practices in connecting to the energy system and exploring potential demand-response strategies (SO3).
- Selecting relevant case studies from EU Member States and third countries to contrast practices and derive valuable insights (SO4).
- Identifying policy recommendations to improve integration (SO5).

[14] Optimierung der Synergien zwischen Rechenzentren und Energiesystemen (DCESS) - Borderstep Institut

The focus of this contribution is on SO3 and SO4. In SO3, EIIs, from sectors like construction, manufacturing or agriculture have been reviewed for BATs that enable them to be successfully integrated into electricity, heating or water systems. For electricity system this includes services to the grid, load shifting, peak load reduction, demand reduction, energy efficiency measures, storage or integration of renewables. For heating system this includes waste heat recovery, reducing fuel demand or utilizing heat more efficiently. For water systems this includes reduction of demand, more efficient usage or efficient water treatment measures. The collected BATs are ranked according to selected criteria to assess the applicability of the BATs to data DCs. From a large number of BATs from different sectors, two from electricity, two from heat, two from water and the two best overall were selected for more in-depth evaluation.

Furthermore, there are already several best practice examples of DCs that interact with energy and water systems in an ideal way. Case studies with a focus on EU member states and with a good balance in terms of size and purpose of DCs were selected. The case studies were evaluated according to selected criteria to assess the relevance of the case studies as best practice examples in terms of their integration into energy and/or water systems. From a large number of case studies, the best two from electricity, two from heat, two from water and the top two overall were selected for more in-depth evaluation. Through interviews and literature review KPIs and lessons learned for operators, policy advisors, facility planners and designers or energy and water system operators were gathered and processed.

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CONFERENCE TOPIC

- Renewable Heating and Cooling including high temperature applications
- Solutions for Energy Efficiency
- Coupling of Energy Sectors
- Future District Heating and Cooling Technologies
- Finance and Business Models
- Excess Heat Energy and Resource Recovery from Low-grade Sources

MULTIFUNCTIONAL BUILDING ENVELOPE WITH THERMAL COMPONENT ACTIVATION IN WOOD

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SUMMARY

Multifunctional building envelopes can contribute to affordable housing in urban areas or to the reduction of CO_2 emissions and energy consumption in new buildings and renovations. The multifunctional façade in timber construction developed and investigated in this study for new construction and in the future also for renovation with integrated heat and cold dissipation and ventilation with façade-integrated photovoltaics with the possibility of modular expansion for serial and widespread application is the next step towards climate-neutral building. For this purpose, a metrological investigation and optimisation of thermal component activation (TABS) of solid wood building components, their heat emission and absorption to and from the inside and outside, as well as the increase of the utilised storage mass through thermal component activation, is carried out. The energy demand and efficiency as well as the heating and cooling performance of the TABS and the influence of the covering in terms of covering thickness and material are investigated as well as the energy flexibility through storage of the energy in the building components.

Keywords: renewable heating and cooling, TABS, thermal storage, decarbonisation in buildings

MAIN SECTION

Due to the climate and energy crisis, the construction industry is facing challenges such as the creation of housing in urban areas or the reduction of CO_2 emissions and energy consumption of living space in urban areas. Multifunctional building envelopes can contribute to this and to user comfort in both new buildings and renovations. They represent building envelopes with integrated building services equipment such as mechanical ventilation or heat and cold dissipation. At the Salzburg University of Applied Sciences, multifunctional façades have been developed and successfully tested for renovations and thermal activation of existing walls (Hinterseer, S. et al., 2019) and used and investigated as sound absorbers for outdoor spaces (Portugaller, B. et al, 2018). The multi-functional façade in timber construction investigated here for new construction and in future also for refurbishment with integrated heat and cold dissipation and ventilation with the possibility of modular expansion for serial and widespread application is the next step towards climate-neutral construction.

Figure1: Installation and mounting of the multifunctional facade in the test stand

The research objectives are as follows:

- Investigation and optimisation of thermal component activation (TABS) of solid wood building components, their heat dissipation and absorption to or from the inside and outside, and the increase of the used storage mass through thermal component activation.
- Energy demand and efficiency as well as heating and cooling performance of the TABS and influence of the covering in terms of covering thickness and material
- Energy demand and efficiency with yield-controlled energy production through photovoltaics and energy storage
- Energy flexibility through storage of thermal energy in the building components or in the different layers
- Behaviour of the overall system and thermo-hygric behaviour of the solid wood component made of CLT

During system development, initial simulations were carried out to determine the required areas for component activation and room temperature control, taking into account the exposure area. This was based on a previous research project "aHolz" (Heidenthaler, D. et al.,2021) and the master's thesis by Daniel Heidenthaler (Heidenthaler, D. 2020), which investigated component activation in cross laminated timber. Component simulations were subsequently carried out with the help of the calculation and simulation program HTflux (version 1.10). HTflux creates high-resolution, two-dimensional simulations of heat and moisture transport in building components and was used for variant studies on flow temperatures, the use of heat-conducting sheets and the position and use of the two activation levels. In the dynamic building simulation with the IDA ICE software, version 4.8, a building model is considered that includes the room and room envelope surfaces of the test room and the multifunctional façade.

With the help of the building simulation, all installed components can be mapped and realistically tested. As a result, a prototype of the façade element with a size of 2.45 m x 4.46 m could be manufactured. The CLT panel is thermally activated on two levels (inside and outside) to find out how a higher storage mass can be used and how this interacts with the room-related control system. It is investigated how energy flexible the space becomes through this façade, i.e. how much renewable energy can be stored in the building component and how long the space does not require any additional energy, taking indoor comfort into account. This will be done by analysing the monitoring data from the first winter 23/24, for the months of November and December.

CONFERENCE TOPIC

Coupling of Energy Sector
Emerging heat and cold storage
Solutions for Energy Efficiency
Sustainable Renovation

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ENHANCING SOLAR WATER HEATING SYSTEMS (SWHS) SUSTAINABILITY AND CAPACITY BUILDING IN BHUTAN

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CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications.

SUMMARY

The Bhutan Department of Energy, supported by the Austrian Development Agency, is actively promoting Solar Water Heating Systems (SWHS) in the building sector. The initial phase of the project, following the installation of 16 SWHS, encountered issues affecting system design and functionality. To address these challenges, the DoE engaged AEE-INTEC to provide intensive training and assess existing SWHS systems. The primary objective was to enhance the skills and knowledge of users, beneficiaries, installers, and implementers for sustainable SWHS operation. Through several workshops and installations, the project has successfully contributed to Bhutan's energy diversification goals, generating an estimated 533 kW of power. However, challenges remain, as many potential users lack essential skills and qualified suppliers and installers are limited.

INTRODUCTION

In Bhutan, the Department of Energy (DoE), with support from the Austrian Development Agency (ADA), is actively promoting Solar Water Heating Systems (SWHS) in the building sector. The initial phase, involving the installation of 16 SWHS, encountered issues leading to operational problems. To address these challenges, the DoE engaged AEE-INTEC to enhance the skills and knowledge of all relevant stakeholders.

Between 2020 and 2023, experts from AEE-INTEC provided intensive theoretical and practical training, focusing on SWHS installation and the assessment of previously installed systems. The objective was to ensure the sustainability of SWHS under the grant-funded project "Promotion of Renewable Energy and Energy Efficient Technologies in the Building Sector, 2020–2023." This initiative aimed to empower users, beneficiaries, installers, and implementers with the competencies required for the effective utilization and maintenance of SWHS.

The DoE remains committed to further strengthening the technical capacity of various groups, including end users, suppliers, installers, and government officials. This effort is vital for the sustainable promotion of SWHS and aligns with Bhutan's energy diversification goals. By the end of March 2023, over 41 SWHS systems were installed in the public and residential sectors, collectively capable of generating approximately 533 kW of power. This significant achievement directly contributes to diversifying energy sources, enhancing energy security, and aligning with targets outlined in the 12th Five-Year Plan.

While the demand for SWHS is growing, many potential users lack in-depth knowledge and the skills required for effective operation and maintenance. Moreover, the availability of qualified and certified suppliers and installers remains limited in the country. Ensuring a robust framework for post-installation support is crucial for the long-term sustainability of SWHS in Bhutan.

Fig. 1: team of technicians, installers and beneficiaries, finishing an installation of an improved SWHS in Bhutan

REDUCTION OF INDUSTRIAL STEAM SYSTEMS TEMPERATURES AS AN ENABLING MEASURE FOR DECARBONIZATION

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SUMMARY

The non-energy-intensive industry that requires process heat includes a large number of companies, but in total they account for around half of the energy consumption of the production sector in Austria. The majority of the energy used in the steam or thermal oil systems is based on gas. This means that higher temperatures or pressures can be achieved with only small losses, but this reduces the costs of the steam or thermal oil system because smaller dimensions are required, for example for heat exchangers or pipes. In this paper we analyze to what extent high temperatures prevent effective decarbonization with low-exergy sources like geothermal energy, solar thermal energy, waste heat, and in particular process heat generated using high-temperature heat pumps, and how integration of these technologies is still possible. We conclude that reducing system temperatures is an effective measure or even a prerequisite for decarbonization.

INTRODUCTION

The so-called decarbonization of industry must be promoted in all sectors. While the energy-intensive industry - including the hard-to-abate sectors - faces major challenges, solutions have already been outlined and these mostly large companies are intensively engaged with developments in this direction. Meanwhile, non-energy-intensive companies account for around half of industrial energy consumption, with thousands of companies in Austria alone and individual companies having low energy consumption (in relation to large industries). These companies often do not have a person specifically or exclusively responsible for energy.

The energy consumption of companies in the non-energy-intensive sector, which require process heat, is usually in a range of up to approx. 200 °C (steam systems) or up to 300 °C (thermal oil systems). In contrast, there are climate-neutral supply options such as geothermal energy, solar thermal energy, waste heat, and in particular process heat generated using high-temperature heat pumps, which are indicatively available at temperatures of up to 150 °C.

In this paper we assume that a reduction in system temperatures is required for the effective integration of the mentioned low-temperature options. We explain why the system temperatures are presumably too high and how integration is possible. We also state that our survey shows that system temperatures have a lock-in effect and that companies' primary choice for new or replacement systems will continue to be a gas-fired system at the end of 2022.

METHODS

To present the status quo, we were able to rely on contacts with a large number of companies and their energy and process data. With a sample size of 20, these companies represent a small but meaningful sample of the companies in the focused area of non-energy-intensive industry.

RESULTS

To represent the status quo of companies with process heat requirements, energy and process data were compiled anonymously from documented company contacts. These represent a sample of companies in the focused area with process heat requirements in the lower temperature level up to approx. 200 °C. The results show that process heat is mostly provided from gas. If biomass is provided, this is usually available internally within the company. Peak loads are provided by correspondingly high outputs/capacities of gas-fired boiler or direct combustion systems. Specific peak load coverage by means of separate peak load systems or even using other energy sources is usually not possible. What most companies have in common is that they have established heat recovery measures or cascading heat use.

Green gas and the direct use of renewable electricity should be used as benchmarks for the changeover. These solutions can also cover high process temperatures and non-energy requirements. Medium process temperatures can be provided via biomass. The remaining solution options can be summarized primarily as low-temperature alternatives: geothermal energy, solar thermal energy, waste heat and high-temperature heat pumps, which primarily use residual heat. As a working definition, an indicative upper temperature limit for these four low-exergy technologies of approximately 150 °C is set.

High-quality energy sources can be saved with different solutions: (i) Processes with high temperatures are supplied separately and lower temperature levels are supplied at the appropriate exergy level. (ii) Another solution is to reduce process temperatures, whereby processes with previously higher temperatures are reduced to the absolutely necessary level and can then ideally be covered with low-exergy technologies. (iii) If there are processes in which the majority of the energy quantity exceeds the temperatures of the low-exergy technologies, they can first be preheated and then reheated with high-quality energy sources. (iv) By means of time separation, an alternative heat source such as waste heat can be used for at least six months, ideally longer. For the rest of the year, coverage is provided by the existing energy system. The application of potential solutions must be examined individually.

It can be observed that companies are considering alternative options, but (i) a gas boiler remains the standard solution for planned expansions and (also for this reason) (ii) a reduction in process temperatures - and thus the prerequisite for making some of the alternatives possible - not be considered as a solution. Accordingly, there is a lock-in effect for high process temperatures and the need for high-quality energy sources.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers: Renewable heating and cooling, including high temperature applications

TOWARDS A CERTIFICATION STANDARD FOR EUROPEAN CLIMATE NEUTRAL RESIDENTIAL BUILDINGS

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SUMMARY

The paper describes a methodic proposal for the certification of residential buildings and associated digital tools. These are oriented towards economic compliance with the Paris climate protection goals and the UN Sustainable Development Goal SDG 7. The presented "*climate-neutral buildings*" start methodology was developed on the *sustainable data platform* (*sdp*) as an evidence-based solution approach. The methodology consistently links personal CO_2-footprints with the efficiency control of heating systems and buildings up to emission from use and construction of buildings. The paper discusses the *sdp* data model developed from long term monitoring and controlling of efficient buildings, solar- and climate protection settlements in Germany and its use in digital tools. It shows ways to achieve EU taxonomy-compliant certification of the European stock of residential buildings. The paper presents first prototype applications in form of digital climate protection tools with their benefits for building owners and business models of metering and services companies.

INTRODUCTION

Regarding the EU's 2030 GHG reduction targets and relating national targets recent projections "with additional measures" suggest a considerable gap towards 2030 esp. in the building sector. While effective measures are urgently needed there exists no data driven basis for their control. Identified reasons are missing uniformity and relevant information for planning-decision making, lacking compatibility of EPCs and transparent emission factors published e.g. monthly by Eurostat-European Commission.

Regarding energy sources there is a lack of clear and harmonised principles, e.g. for the assessment of district heating, hydrogen and also bioenergy, as the most important renewable energy source in Europe. Regarding buildings there is a lack of methods to verifiably and effectively direct financial resources towards low housing costs and climate neutrality.

The paper analyses existing regulations, calculation methods and certification systems regarding their suitability for transforming the European residential building stock in line with the Paris climate protection goals and SDG 7 in a timely manner. The paper incorporates findings from policy and transformation research, and identifies disruptive influences that are difficult to regulate due to "noise", e.g. in the form of media campaigns.

A lack of evidence-based methods aligned with the Paris climate protection targets and housing cost burdens (SDG 7) are identified as the main causes of significant performance gaps, particularly in NZEB and complex systems. In addition, there is a lack of suitable metering standards for analyzing and closing technical performance gaps in a timely manner. There is furthermore a need for evidence-based CO_2-evaluations and simplified standards to include the significant emissions from construction.

TASK

To fulfil climate protection targets, the actual emissions must be measured for a representative number of buildings or micro-grids. The dynamics of climate protection measures for the building stock can be measured and controlled in this way. Methodology and metering must be harmonised for this purpose, considering the conflicting demands of transparency and data protection esp. for single family buildings.

Stakeholders in the overburdened construction sector must be reliably informed about feasibility, investments, costs, implementation, and operational management and supported in their daily tasks.
Robust, evidence-based standard routines must be developed for the climate-friendly retrofitting, construction, and operation of residential buildings. These must enable the certification of buildings, digital tools, measuring devices and services and fulfil the requirements of the EU taxonomy reporting.

SOLUTION PROPOSAL

The paper provides a holistic analysis of the control engineering principles and disturbance variables for climate-neutral building stock, of regulation, and data modelling. It shows the *sdp* data model, which has been designed according to the principles of physics and control engineering in accordance with the Paris climate protection target and SDG 7. Climate protection, energy, and resources as well as the degree of energy autonomy are taken into account; costs serve as indicator for social burdens. Indicators are scaled down to the action level of an individual heating system. The associated quality of measuring devices and data is considered.
The start-up methodology of the modelling proposal is based on the planning- and evaluation experience from solar and climate protection settlements and experience in regional energy monitoring. The practical approach allows to simplify the overcomplex regulations for residential buildings.

Fig. 1 shows the "climate neutral buildings" features" Real Housing Emission map", the “CO_2-trend” chart with long-term CO_2 emissions and associated increasing decarbonisation targets as well as a monitoring view for timely reaction in case of performance gaps.

The start methodology is openly documented; aim is a further collaborative development for the European residential building stock. The associated "*climate-neutral buildings*" tool is available as a prototype for testing by other participants in compliance with the *sdp*-codex. The article reports on its use for property companies, planned AI-supported research projects for district heating, heat pumps and gas solar thermal energy and its use in an all-electric "Reallabor" for the energy transition.

LINKS

Informationen: https://sustainable-data-platform.org/climate-neutral-buildings/
Methodic (D): https://sustainable-data-platform.org/methodik/

CONFERENCE TOPIC

This abstract refers the following topics: BUILDINGS: Solutions for Energy Efficiency, Digitalization for Future Energy Systems, Policies, IT Technologies and Artificial Intelligence, Finance and Business Models, Smart Services and System Operation.

SOLAR COOLING FOR THE SUNBELT REGIONS – HIGHLIGHTS FROM TASK 65 ACTIVITES

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SUMMARY

The energy demand for air-conditioning is growing faster than any other energy consumption in buildings. The main share of the projected growth for space cooling comes from emerging economies and will more than triple by 2050 to 6,000 TWh/a globally (IEA 2018). Therefore, the IEA SHC Task 65 "Solar Cooling for the Sunbelt Regions", started in July 2020, is focusing on innovations for affordable, safe and reliable Solar Cooling systems for the Sunbelt regions. The innovation is the adaptation of existing concepts/technologies to the Sunbelt regions using solar energy, either solar thermal or solar PV. The importance of the topic is reflected in the high number of experts participating in IEA SHC Task 65, especially as 50% of the Task experts come from industry and SMEs. This paper presents the Task 65 results of the different activities carried out in last 3.5 years and highlights the ongoing research projects.

Keywords: Solar thermal cooling, PV cooling, Sunbelt regions, IEA SHC Task 65

INTRODUCTION

Global energy demand is growing, although its growth rate is less than in the past. Nevertheless, by 2040 an increase of 30% is projected by OECD (2017). Nowadays air-conditioning accounts for nearly 20% of the total electricity demand in buildings worldwide and is growing faster than any other consumption in buildings (IEA 2018). The undisputed rationales for the increase are global economic and population growth and thus rising standards of living. Growth in the demand of cooling is especially driven by countries with high temperatures. Three emerging countries (India, China, Indonesia) contribute to more than half of the annual growth rates. Additionally, the efficiency of the air-conditioners varies considerably. The most common systems run at half of the available efficiency (IEA 2018). If measures are not taken to counteract this increase, the space cooling demand could triple by 2050.

Nowadays e.g. in India, 30% of total energy consumption in buildings is used for space cooling which reaches 60% of the summer peak load. This is already stretching the capacity of the Indian national electricity supply dramatically (Patwardhan et al. 2012). In other countries peak load through air conditioning reaches >70% in hot day (IEA 2018). Moreover, in the countries of the Association of Southeast Asian Nations (ASEAN) the electricity consumption increased 7.5 times from 1990 to 2017 (IEA 2019). With the increase in demand comes the increase in the cost of electricity and summer blackouts, which have been attributed to the large number of conventional air conditioning systems running on electricity. As the number of traditional vapor compression chillers grow so do greenhouse gas emissions, both from direct leakage of high GWP refrigerant, such as HFCs, and from indirect emissions related to fossil fuel derived electricity consumption.

Solar air-conditioning is intuitively a good combination, because the demand for air-conditioning correlates quite well with the availability of the sun. The hotter and sunnier the day, the more air-conditioning is required. Interest in solar air-conditioning has grown steadily over the last years. The latest numbers of worldwide installations in 2023 showed nearly 2,000 systems (IEA SHC 2023). Solar air-conditioning can be achieved by either driving a

vapor compression air-conditioner with electricity produced by solar photovoltaic cells or by solar thermal heat to run a thermally driven sorption chiller.

The knowhow capitalised in OECD countries (Europe, US, Australia, etc.) on solar cooling technology (both thermal and PV) is already very great, but very few efforts have been made to adapt and transfer this knowhow to Sunbelt countries such as Africa, MENA, Asian countries, which are all dynamic emerging economies They are also part of the global increase in demand for air conditioning (AC), where solar cooling could play an important role, as these are all highly irradiated regions of the world.
Therefore, the present IEA SHC Task 65 aims to develop innovations for affordable, safe and reliable cooling systems for the sunbelt regions worldwide (sunny and hot climates, between the 20th and 40th degrees of latitude in the northern and southern hemisphere). It should cover the small to large size segment of cooling and air conditioning (between 2 kW_c and 5,000 kW_c). The implementation/adaptation of components and systems for the different boundary conditions is forced by cooperation with industry and with support of target countries like UAE and India through Mission Innovation (MI) Innovation Community on Affordable Heating and Cooling of Buildings (IC7).

So far (Nov. 2023) 83 experts from 17 countries and 48 entities are listed. Actively participating entities include 50% from industry, consultants and 50% from universities and institutes. The IEA SHC Task 65 has completed several activities, so highlights of these results will be presented. Among these are (i) a GIS tool for investigation of climatic conditions & applications, (ii) buildings and process optimization potential, (iii) show cases on adapted solar cooling systems for sunbelt regions, (iv) design guidelines (v) best practice and lessons learned (technical and non-technical), (vi) literature research results on systems, controllers and combined building & solar cooling integration, (vii) assessment methods, (viii) techno-economic results of show cases and (ix) financing models.

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CONFERENCE TOPIC

Renewable Heating and Cooling
Policies for Renewable Heating and Cooling

EVALUATION OF THE RENEWABLE ENERGY AND INDUSTRIAL SYNERGY POTENTIAL IN THE INDUSTRIAL ZONE OF CALLAO/PERU

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SUMMARY

In the industrial zone of Callao in Lima/Peru more than 60 companies of several industrial sector such as textile, foundry, metal work, chemicals etc. were analyzed regarding the implementation of renewable energies in their production processes and possible energetic synergies between neighboring companies such as industrial heat networks or energy communities. Data was collected based on previously conducted energy audits, energy consumption lists and site visits. Based on the database, an energy balance of the whole industrial area was established and the companies with their energy consumptions were mapped in a GIS program. The potential of photovoltaics, waste heat, heat pumps, biogas production and the resulting possible CO2-savings were calculated for all project companies. Additionally, three case studies were chosen to calculate in detail the investment, savings, and revenues of a renewable energy project. For these examples, financing models were provided, and the legal framework was illuminated.

INTRODUCTION

Renewable energies and energetic synergies in industrial processes are still quite unknown in Peru due to the cheap fossil fuels, a missing legal and policy framework, and the lack of local suppliers. The aim of this project is to introduce low-carbon technologies in the Peruvian industry in the pilot region of Callao.

METHODS

Data was collected from four different sources: The main source were reports from energy audits that were conducted earlier in the project by Peruvian energy efficiency experts. The reports contained information on electricity and natural gas consumptions and descriptions of the industrial processes. Another data source was energy consumption lists from the energy ministry that broadened the number of considered companies and therefore helped to get a more comprehensive picture of the Callao industrial zone. To collect some specific data on waste heat and biogenic residues, questionnaires were created and sent to the companies. The most valuable data source was nevertheless the direct communication with the company representatives during a trip to Lima.

For all project companies, the following factor-based potential calculations were carried out:

- Calculation of the PV generation potential based on the available surface area and calculation of the ratio with the necessary surface area to theoretically cover the whole electricity demand by PV.
- Calculation of the total amount of waste heat with industry-specific factors based on the natural gas consumption.
- Calculation of waste heat potential for heat pumps from cooling with industry-specific factors for cooling demand based on the electricity consumption.
- Calculation of heat demand below 100°C as heat sink for heat pumps.
- Determination of the biogas potential of several fish factories involved in the project.

Based on this the possible CO2 savings are determined and the potential in the entire industrial zone can be assessed.

The localization of all the companies with their attributes from the database on an openstreetmap-based map was carried out using GIS software. The possible visualizations of each company include their data source, natural gas and electricity consumption and CO2 emissions. Filters for several attributes can be applied and a fact sheet appears when selecting a company on the map. The mapping allows to easily identify possible hubs of industrial synergies.

Workshop & Site Visits

During a stay in Lima a workshop in Callao was held with 90 participants including industry representatives, government officials, consulting firms and technology manufacturers. It included project related presentations and interactive sessions to jointly develop & discuss potentials, possible cooperation ideas and the identification of technological, legal, and financial obstacles in Callao.

Apart from the workshop 7 Site Visits in selected companies of different industries with particularly high potential and interest were carried out. The goal was to better understand their industrial processes, discuss individual opportunities and cooperation partners and deliver individual factsheets and potential assessment.

PRELIMINARY RESULTS AND CONCLUSIONS

Based on the analysis and site visits, three case studies were selected to calculate exemplarily the investment costs, monetary savings and revenues such as the savings of fossil fuels and CO2 emissions:

- Waste heat extraction from glass factory: ~20 000 MWhth/a waste heat available that is currently released to the environment at >900°C. Approx. 1.5 million €/a revenue, 4 million invest, 11€/MWh LCOH, 5400 t/a CO2-equiv. savings.
- Biogas generation from organically loaded wastewater in paper mill: ~7700 MWh/a biogas production possibleApprox. 600 000 €/a savings, 1.1 million invest, 11€/MWh LCOH, 2100 t/a CO2-equiv. savings.
- PV power generation on roof surfaces of a shipyard: 27 MWp installed capacity possible, thus >50 Mio. kWh/a electricity generation. Approx. 400 000€ savings & 1,9 Mio.€ revenues/a, 34 Mio. Invest, 6ct/kWh LCOE.

The development of financing models, analysis of the legal framework and potential calculations is ongoing.

CONFERENCE TOPIC

Excess Heat Energy and Resource Recovery from Low-grade Sources

OPTIMIZATION OF MECHANICAL FRICTION WASHING IN THE CIRCULAR ECONOMY OF PLASTICS FOR ENERGY SUSTAINABILITY

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SUMMARY

The need to transition from a linear to a circular plastics economy is driven by global challenges related to improper plastic waste disposal. Recycling plants are facing the challenge of finding resource and energy efficient solutions for all steps of plastics recycling. Washing plastic flakes is one of the crucial process steps, with the aim to find washing processes that require minimal water, energy and chemical input while ensuring high flake quality for subsequent processing. The study proposes the use of surface contamination in terms of washable Chemical Oxygen Demand (COD) as a promising parameter to evaluate the cleanliness of polypropylene (PP) and discussing required washing efficiency that is enhanced through high temperature washing and higher caustic soda (NaOH) concentrations. Further research and cost-benefit analyses are required to mitigate environmental impacts. Conducting large-scale experiments with the LINDNER® friction washer is crucial for advancing this transition.
Keywords: plastic, recycling, energy, circular economy, wastewater

INTRODUCTION

Improper disposal of plastic waste has led to global problems, including widespread pollution, resource depletion and high energy consumption. Recent data from the European Union shows a substantial increase in plastic production and waste, with 57 million tons produced and 30 million tons discarded annually[1]. Globally, plastic production reached 390.7 million tons in 2021, with further growth projected[2]. By 2050, it is estimated that plastics will contribute up to 20% of global oil consumption, according to the World Economic Forum[3].
However, polymers are essential to many aspects of modern life, improving quality, safety, and health. To balance their importance with environmental concerns, it is essential to adopt sustainable practices. The aim is to shift from the current linear plastics economy to a circular economy, promoting the responsible use of plastics.

MATERIAL AND METHODS

Sample of dirty PP No. 414 was supplied by Altstoff Recycling Austria and shredded to 30 millimeters sieve at the Linz Institute of Technology Factory. To wash this material, the small-scale simulation method was used in the Miele® Professional industrial washing machine, containing 3 kilograms of PP flakes in 18 liters of clean water for 5 minutes for each treatment. The treatments were carried out in duplicate and alternated in water temperature (20°C or 80°C) and NaOH concentration (0% or 0.5%).
During the washing process, the plastic flakes were stored in washing bags and, after this stage, they were rinsed twice, for 5 minutes each time. The wash water from the washing process was collected for COD analysis using the Cell Test Supelco® dichromate method with the aid of the Spectroquant® NOVA 60 photometer. The washed and rinsed plastic flakes were dried in an oven Memmert® for 24 hours at 60°C. After this period, an "absolute wash" was carried out with these washed plastic flakes in a beaker for 15 minutes with 2% NaOH at 85°C at 800 revolutions per minute to remove all the remaining COD (surface contamination after washing). The wash water from the surface contamination after washing was also collected for COD analysis.

The COD data was used to investigate the applicability of COD as a parameter for evaluating the plastic flake cleanliness and to evaluate the efficiency of the different washing treatments. The following are equations I and II applied to calculate the washing efficiency of the treatments based on the COD calculated in the wash water.

$$WCT = \frac{mg\ COD}{g\ plastic} \qquad \text{(eq. I)}$$

WCT: washable contamination (in $mg.g^{-1}$)

mg COD: COD measured in the wash water (in mg)

g plastic: amount of plastic washed (in g)

$$\eta = \frac{WCT_{washed\ off}}{WCT_{after\ washing}} \qquad \text{(eq. II)}$$

η: treatment washing efficiency (in %)

WCT washed off: washable contamination during washing treatment (in $mg.g^{-1}$)

RESULTS AND DISCUSSION

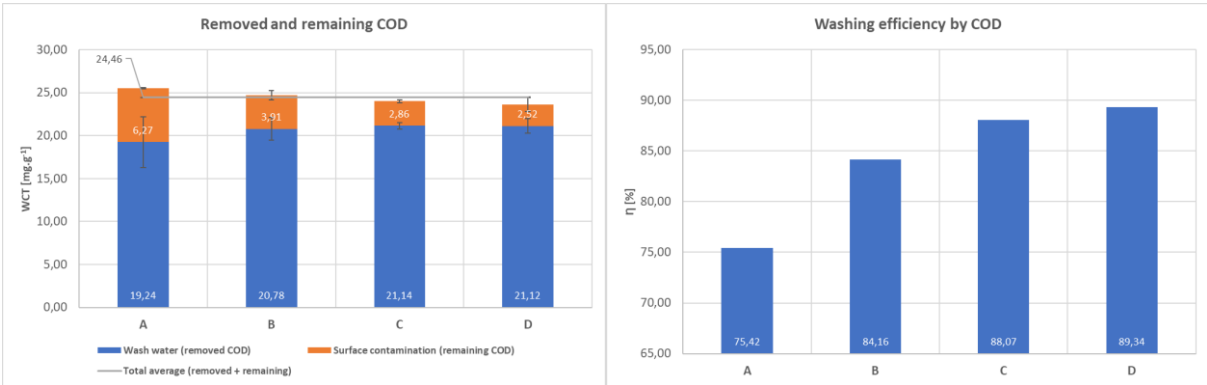

Fig. 1: COD balance (left side) and washing efficiency by COD (right side) of treatments A (20°C and 0% NaOH), B (80°C and 0% NaOH), C (20°C and 0.5% NaOH) and D (80°C and 0.5% NaOH).

Test D showed the highest efficiency (89.34%), followed by tests C (88.07%), B (84.16%) and A (75.42%), suggesting an expected enhancement by higher temperature and higher chemical usage. Largest increase in washing efficiency was detected by using NaOH as detergent at constant temperature of 20°C (12.65%), followed by temperature increase without presence of NaOH (8.74%). This underlies the importance of holistic studies, evaluating the effects of chemical usage (e.g., wastewater treatment effort) as well as energy demand for hot washing. The paper will discuss these dependencies linked to flake quality analysis to show first pathways on energy and resource efficient plastic flake washing for high quality recycled products.

CONCLUSIONS

The results suggest that COD is a very promising parameter to evaluate the cleanliness of PP. Furthermore, showing that washing plastic flakes combined with high temperatures and higher concentrations of NaOH is more efficient. Further studies are needed to confirm the possible washing efficiency increase for various materials and in large scale washing lines. Also, to reduce energy consumption and environmental impacts, a cost-benefit analysis should be carried out between the energy demand for heating the wash water versus energy and chemical needs, including impacts on wastewater treatment, when applying NaOH. In the long-term, ideal operating conditions need to be proven in large-scale experiments with a view to transforming the current linear plastic economy into a circular economy.

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CONFERENCE TOPIC

Solutions for Energy Efficiency, Centres for circularity

NOVEL POLYOLEFINIC MATERIALS FOR PIT THERMAL ENERGY STORAGES

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SUMMARY

Pit thermal energy storages (PTES) enable the combination of various renewable energy sources, increasing the flexibility of the energy system. Working as a buffer storage, the recently commissioned PTES in Høje Taastrup (Denmark) is connecting several heat producers and consumers. 25 annual energy utilization cycles and an operating temperature of 90°C are envisaged allowing for a higher energy density. A key element of such higher temperature PTES is a liner with an improved endurance temperature. Hence, novel liner materials were developed and screened in a highly accelerated manner. The implemented testing methodology is based on elevated exposure temperatures and miniaturized specimens. An acceleration factor of up 20 was achieved for polyolefinic liner formulations. To determine the endurance time tensile testing, thermal analysis and IR-spectroscopy was performed on micro-specimen exposed to hot air or water. At a constant temperature of 90°C and a liner thickness of 3 mm a lifetime of 25 years was estimated for the best performing PP-HTR liner material.

CASE STUDY - BUFFER STORAGE IN HØJE-TAASTRUP

The PTES in Høje Taastrup (Fig.1, right) is acting as a buffer storage with a capacity of 3.300MWh and is linked to a transmission line that connects various heat producers (4 CHP plants, 3 waste incineration plant, reserve and peak load power plants, 2 TES) in the greater area of Copenhagen (around 5000 MW). With up to 25 energy utilization cycles per year and a permanent water temperature of 90°C, it is designed to optimize the electricity and heat production of the connected power plants (Fig. 1, left). The storage brings significant value by increased production from highly efficient CHP (Combined Heat and Power) and waste incineration plants, reduced peak loads, and bypass operation. That's of relevance especially during winter time (Wetzel, (2023).
The investment costs for the 70,000 m³ PTES in Høje Taastrup amounted to 5.3 M€, which is equivalent to 76 €/m³. Larger multi-functional or buffer storages with a volume of 500,000 m³ require investment costs of about 40 €/m³. In comparison, the investments costs for a steel tank storage of the same size would be a factor of 1.8 higher (Bruus, 2019). Annual operational benefits of up to 1.5 M€ are estimated.

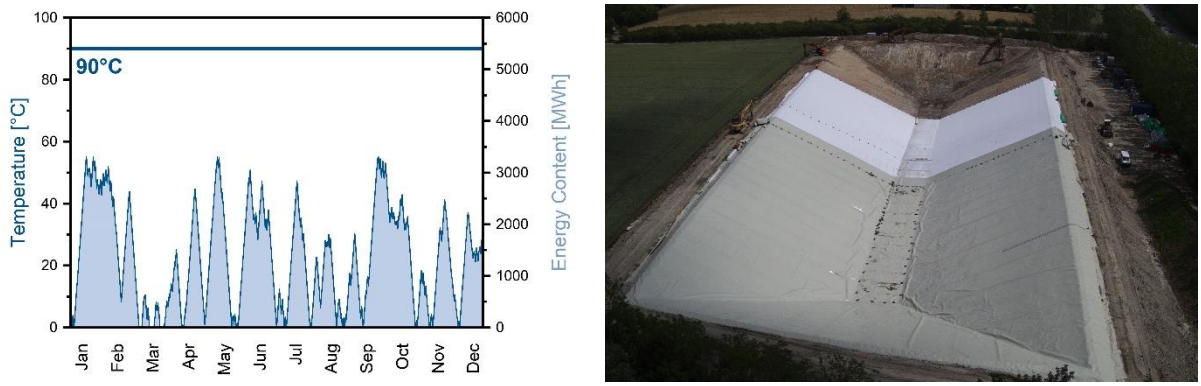

Fig. 10: Forecast of the water temperature and the energy content for the multifunctional PTES in Høje Taastrup for 2025 (left), and drone picture of the PTES during installation of the PP-HTR liner (Arlborg CSP) (right).

LIFETIME ESTIMATION FOR POLYOLEFINIC LINER MATERIALS

The lifetime estimation approach used for polymer liners is based on a cumulative damage model implemented and further developed by Wallner (2016), Grabmann (2018) and Peham (2022). Temperature profiles of the PTES, extrapolated experimental ageing data and the effect of specimen thickness is considered adequately. For characterization of the long-term behaviour of PE-RT and PP-HTR liner materials with different stabilizer packages, micro-specimen with a thickness ranging from 50 to 500 µm were prepared using a home-built cutting tool. While PE-RT specimen were more affected by hot water, PP-HTR were more prone to ageing in hot air environment (Grabmayer, 2014). Exposure temperatures were ranging from 65 to 135°C. After defined time intervals specimen were removed and degradation indicators were evaluated (Fig. 2). Therefore, tensile testing, thermal analysis and IR spectroscopy was performed. Acceleration of the ageing process by specimen thickness reduction and exposure temperature increase resulted in an acceleration factor of up to 20. For the PTES in Høje Taastrup a constant water temperature of 90°C and a liner thickness of 3 mm was assumed. For the novel PP-HTR material a lifetime of 25 years was estimated. In contrast, just 6.5 years were deduced for the well-established PE-based liner materials.

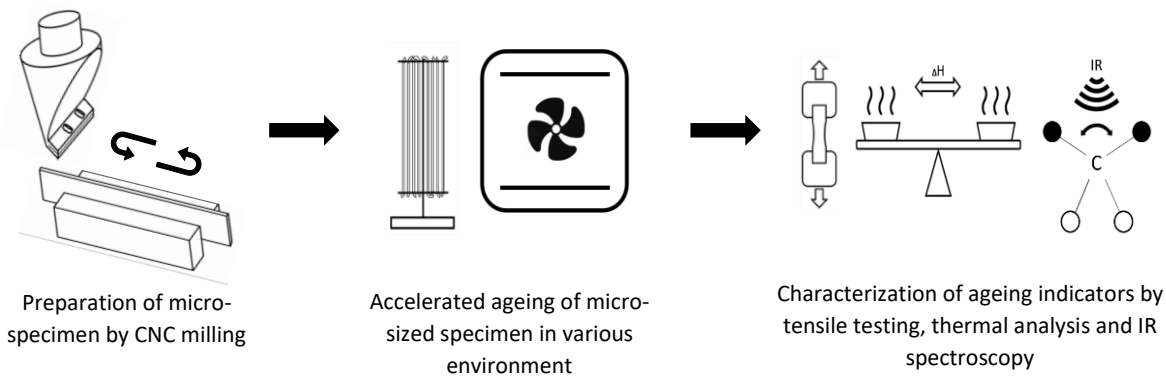

Fig. 11: Methodological approach for accelerated ageing testing of polyolefin micro-specimen.

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CONFERENCE TOPICS

Emerging heat and cold storage, Coupling of Energy Sectors, Future District Heating and Cooling Technologies

RENEWABLE ENERGY COMMUNITIES AND REDOX FLOW BATTERY: SYSTEMIC INNOVATION IN THE MUNICIPAL PLUS-ENERGY DISTRICT OF WEIZ

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SUMMARY

Key Words: Renewable Energy Community, Redox Flow Battery, Tariff model, Climate-neutral districts
In the research project “EnErGie Werk Weiz”, the integration of a redox flow battery shared by all members within a renewable energy community was investigated. The battery is intended to increase the amount of PV-energy, used by the community members. An additional integration into a control reserve pool was also investigated but could not be realised due to legal uncertainties. New operation and tariff models as well as real-time data from the members are required to integrate the battery and to create the framework for a climate-neural district. Based on an energy community with 19 participants consisting of SMEs located at a business park in Weiz an economic use case could be found, where all stakeholder benefit. However, when comparing the economic effects with a use case without a battery, it is clearly shown, that not installing a battery is more sensible from an economic standpoint. In this respect, the non-monetary advantages of the battery must also be evaluated.

INTRODUCTION

To increase the share of renewable energy sources and to provide incentives to produce and use the energy locally, the EU renewable energy directive has further developed the process of emancipating the end consumers towards active participants in the energy system. Parts of that directive have been transposed to national law in the “Erneuerbaren-Ausbau-Gesetzespaket” in July 2021, which enables the establishment of so-called renewable energy communities (REC) in Austria. Meanwhile, several RECs are already in operation in Austria and many more will follow soon. While most RECs are limited to the exchange of electricity, other fields of activity, such as storing electricity, are also open to the REC. That is where the focus of the "EnErGie Werk Weiz" project is on, which is investigating the integration and operation of a redox flow battery used jointly within a REC. While in a "classic" REC, allocation and billing is based on smart meter data, real-time data with a much lower time resolution is required to operate a redox flow battery. It is also needed to set up a situation where the investment costs can be refinanced over time. New or adapted operation and tariff models are therefore required.

METHOD

As first step, the potential participants of the REC have been identified and the stakeholder data has been collected. Due to the focus area at the business park in Weiz, the participant structure is primarily made up of SMEs and community-based businesses. However, it is planned to subsequently extent the REC and to include the surrounding households and the existing e-charging structure as shown in Fig. 1.
The redox flow battery was dimensioned by using combination python time series simulation models. The use of the battery was simulated using the efficiency curves for both charging and discharging. The resulting load profile was then introduced into the energy community simulation suite which dynamically allocates the available generation to the different members of the community, depending on their current consumption values. Different battery sizes were evaluated, and various operating and tariff models were examined. In addition of using the battery to increase self-consumption within the REC, the integration of the battery into a control reserve pool was investigated too. By using the battery within different settings, an improvement of the economic efficiency of the

battery was expected. However, the commissioned expert report [1] revealed major legal uncertainties. Therefore, this approach was rejected, and the battery is used exclusively to optimize self-consumption within the REC.

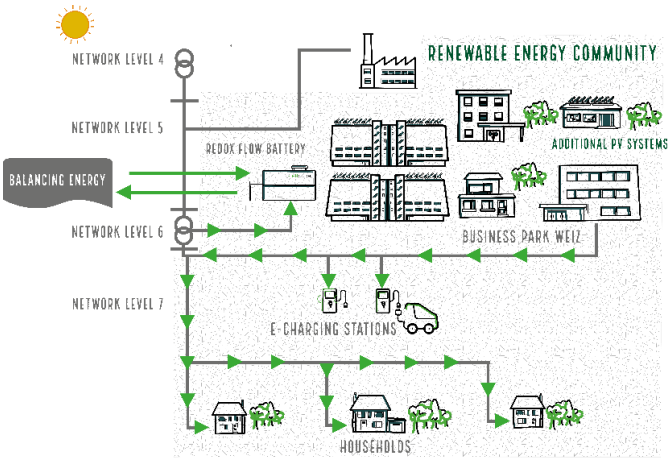

Fig. 1: Schematic illustration of the operation model

Subsequently, practical testing of the storage facility is planned. Commissioning is scheduled for 2024. In addition of installing the storage system, all members will be equipped with measuring devices that enable real-time control of the storage system. The measuring devices will communicate via a dedicated LoRaWAN network.

RESULTS

The calculations have shown that, amongst the options available, the best configuration consists of a redox flow battery with a capacity of 250 kWh in combination with a 400 kWp PV system. It was assumed that this PV system is connected directly to the battery. In that way, grid fees can be reduced, and subsequently the economic efficiency can be increased. The assessment is based on a REC with 19 members with a total electricity demand of approx. 6,700 MWh/a and a PV potential (existing + planned systems of all members in the near future) of approx. 2,600 kWp. An average consumption tariff for grid consumption of 18 cents/kWh and a feed-in tariff to the public grid of 10 cents/kWh was used.

With this configuration the total grid consumption can be reduced from 81 % (5 496 MWh/a) to 64 % (4 316 MWh/a). Around 3 % of this reduction is attributable to the battery, the rest is resulting from participation in the renewable energy community. The tariffs within the REC were chosen in such a way that participation is profitable for all members, the operating costs of the REC are covered, and a positive net present value is achieved for the battery investor. The members of the REC achieve a total economic benefit (savings through purchase from the REC and additional income through feed-in in the REC) of € 57,000 p.a. The investment in the PV system and the battery will increase the capital value by 168,000 EUR after a term of 20 years. Existing subsidies have already been taken into account. It was also assumed that the investment is made with dept capital (effective interest rate of 5 %). An internal interest rate of 4.5% was assumed for the present value method.

An economic use case could thus be found for the jointly used redox flow battery within the REC. However, if the scenario described is compared with the same REC but without a battery, better economic results are achieved. This is mostly due to the high investment costs of the battery storage, which need to be compensated by the members of the community. In this respect, the non-monetary advantages of the battery must also be evaluated, which are for example, the emergency power supply of the installation site and the reduced strain on the grid, as the peak power infeed into the grid by the PV-plant could be reduced.

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CONFERENCE TOPIC

Solutions for Energy Efficiency

THERMALLY ACTIVATED BUILDING STRUCTURES AS FLEXIBILITY OPTION FOR THE ELECTRICITY MARKET

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SUMMARY

Combined with heat pumps, thermally activated building structures (TABS) can serve as a resource of flexibility for electricity markets and the grid. This paper analyses the energy-economic benefit resulting from utilising the flexibility enabled by thermal building inertia. The scope of the study is the Austrian building stock by the year 2040.

INTRODUCTION

The volatility of electricity generation from wind and PV will increasingly challenge grid stability and also lead to price peaks on the power exchanges. Beside typical controllable power plants, also new storage technologies and flexible end consumers ("demand response") are needed to meet the future demand for flexibility. In this context, the use of the thermal inertia of buildings as flexibility is still scarcely considered by the energy industry. This paper aims at quantifying the economic value when leveraging this flexibility potential in the Austrian building stock by 2040. It sums up the results from a study prepared by IIBW and e7 on behalf of the Austrian Ministry for Climate Protection (Amann et al. 2023) and gives directions for the ongoing research project PnP Control TABS (Preisler et al. 2023).

The flexibility potential for the electricity system arises from thermally activated building structures (TABS) and also underfloor heating systems powered by heat pumps. It takes many hours and days for the concrete structures to warm up and just as long to cool down. The control of the heat pumps can thus be adjusted to the requirements of the grid or the electricity market. Flexibility is necessary to ensure that generation and consumption in the electricity system are the same at all times. In this study, flexibility is considered as a resource to shift loads from times of high electricity prices to times of low prices. This also maximises the use of renewable energy, since in times of surplus production through PV and wind, prices on the power exchange are typically low.

METHODOLOGY: MARKET ANALYSIS, BUILDING SIMULATION AND OPTIMISATION MODEL

In a first step, based on the experience of IIBW and a stakeholder dialogue, estimates have been formulated for the expected new constructions and renovations of residential and service buildings in Austria until 2040.

Then, e7 has deployed a methodology featuring dynamic building simulation and optimisation modelling. Different reference buildings were modelled and then simulated over the course of a year, taking into account outdoor temperatures, solar radiation and comfort zones for heating and cooling.

The mathematical optimisation model then suggested a control strategy for the buildings' heat pumps to optimise energy costs in a dynamic electricity pricing scheme. Note, that the main priority is always maintaining the users' comfort boundaries, which means that price optimisation is limited by a certain indoor temperature range in the building. Comparing an uncontrolled scenario (business as usual) with a price-controlled optimised scenario (spot market prices on the day-ahead market with forecast prices and volatilities until 2040), the monetary energy-economic benefit of flexibility from TABS and underfloor heating systems was then calculated.

MARKET TREND FOR TABS AND UNDERFLOOR HEATING

Besides previous construction rates and a forecast of the demographic development, a variety of further input variables were taken into account for the market analysis, estimating future construction and renovation rates. With the support of a network of experts, a plausible penetration of TABS and underfloor heating was assumed for new constructions and renovations and on this basis a market trend for thermally activated building area was estimated until 2040.

Under the assumptions made in the model, it is estimated that the market penetration of TABS in Austria will increase rapidly in the coming years. From about 500,000 m² of newly installed space today, the annual output is expected to increase to over 2.5 million m² by 2040. Cumulatively, this is then close to 30 million m². Underfloor heating will start with a significantly higher volume of currently about 2.5 million m², which will increase to about 4 million m². Cumulatively, this will be over 50 million m² by 2040. In the context of increasing market uptake of smart-ready heat pumps, a significant volume of thermally activated space will be available in Austria in the foreseeable future. This forms the basis for the techno-economic model, quantifying the flexibility potential.

RESULTS: ENERGY-ECONOMIC VALUE OF TABS

Looking at the level of individual buildings, the savings in energy costs that can be achieved through price-optimised operation of the heat pumps result in an average of approx. 22 % in 2025, but up to 50-75 % in 2040, depending on the building type. The savings are generally higher for air-source heat pumps than for ground-source heat pumps, which is because of the higher efficiency of ground-source heat pumps. Electricity generation from building-integrated PV is certainly financially beneficial for the building user, but reduces the benefit from price-optimised electricity supply from the grid. This is especially the case in summer, resulting in higher cost saving potential during the winter months.

Combining these results with the figures from the market forecast, the potential for the entire thermally activated building stock in Austria can be calculated. Accordingly, the annual achievable cost savings sum up to about € 23 million in the year 2040. By far the most important building type in this respect are large-volume residential buildings. Due to higher market penetration, underfloor heating is more important than TABS.

As an interpretation of these results, it can be argued that on the one hand, the relative cost saving potential for individual buildings can be quite high. On the other hand, however, in absolute values the savings are still very small, considering the whole Austrian building stock as a flexible resource. To better understand this effect, it should be noted that only the energy for heating and cooling, but not for hot water, is taken into account in the model. Also, only the pure energy costs are included, but not grid charges, taxes and levies. Beyond the direct cost benefit calculated in this model, there might be other benefits of optimised heat pump control for energy suppliers and grid operators, which are difficult to quantify. Finally, load shifting in low-price periods contributes to better utilisation of renewable energy sources and thus to achieving climate targets.

DEVELOPMENT OF A PLUG-AND-PLAY CONTROL STRATEGY

In order to realise this flexibility potential in practice, the necessary technical requirements for controlling heat pumps are needed on the one hand, but also corresponding offers on the market on the other hand. A specific business model for using the flexibility from heat pumps in component-activated buildings is being developed in the PnP Controls research project.

The aim of the project is to design a standardised plug-and-play control strategy in which an optimisation algorithm reacts to dynamic price signals and also positive or negative flexibility calls can be made by an energy supplier. In the project, the energy supplier is a wind power producer who wants to balance its portfolio in the short term by directly controlling flexible heat pumps and thus minimise balancing energy costs. The latter point could suggest that the cost savings could be even higher as in the model calculated in this paper, as there is also a benefit for the wind power producer, in addition to the exploitation of dynamic prices.

There is certainly a need for further research and awareness raising for testing such concepts in large-volume residential buildings, in which TABS will play an increasingly important role. In this context, real estate developers should be made aware of the advantages of using flexibility and the technical requirements that need to be taken into account during construction and renovation.

ACKNOWLEDGEMENTS

The work published in this paper has been financially supported by the Austrian Research Promotion Agency (FFG) through the study “Bewertung der Bauteilaktivierung als Option für Flexibilität im Strommarkt” and the project PnP Control TABS. The knowledge gained is disseminated to international stakeholders through active participation in the technology collaboration programme IEA ES Task 43 - Standardized use of building mass as storage for renewables and grid flexibility.

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CONFERENCE TOPIC

Flexibility and Stability of Thermal and Electric Grids

AIA4ALL – DEVELOPMENT OF NEW OPENBIM USE CASES FOR HVAC SYSTEM CHECKS AND DYNAMIC SIMULATIONS WITH IDA ICE

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SUMMARY

One objective of the research project AIA4ALL (Zucker, et al., 2023) is to create new open Building Information Modelling (BIM) use cases. As such, a use case for functional tests of the Heating Ventilation and Air Conditioning (HVAC) systems is currently being developed that begins in design development phase of the planning process. Additionally, a use case concerning the linkage between openBIM and the dynamic simulation software IDA ICE (EQUA Simulation AB, 2023) is also under development. First results of these use case developments will be presented in this work, along with the challenges of working in openBIM environment using the open BIM standard Industry Foundation Classes (IFC) (buildingSMART, 2023).

INTRODUCTION

The Exchange Information Requirements – EIR (German: Austausch Informations Anforderungen – AIA) – allows the client to define goals and use cases for a BIM-based construction project. The requirements for the BIM models and the information they contain can thus be derived from the AIA. The AIA thus describes who has to provide which information, when, and with what level of detail.
The BIM execution plan – BEP (German: BIM Ausführungsplan – BAP) builds on the AIA and defines the content and strategy of the collaboration of all parties involved in the project. If the AIA is the BIM requirements specifications, the BAP corresponds to the BIM implementation specifications of the contractors. The BAP is not a static document like the AIA, but is continuously updated throughout the life of the project. The interaction of AIA and BAP is essential for seamless digitization in the construction sector.
The aim of this project is to create a modular, machine-readable AIA that can be seamlessly integrated into the tool landscape of openBIM projects. This is done by developing an open platform for creating use cases for the AIA. The platform should offer the possibility of defining the necessary content, processes, structures, phases and roles and also generating the digital artifacts (config files, IFC property definitions and rules) in order to be able to check the requirements as automatically as possible.

RESULTS

OpenBIM use case "Functional tests of HVAC systems"

Step 1: Operation mode analysis
At an early design stage, this step aims to provide an overview and an early evaluation of the building's HVAC systems. The process includes performance analyses of the building's heating and cooling systems carried out for 20-25 operating points in lieu of the usual two operating points (standard outdoor temperature winter/summer). Thus, avoiding perceivable issues such as oversizing of the heating and cooling systems, frequent part load operation, and the installation of unnecessary plant components. Moreover, the operation mode analysis process can be used to create operating strategies for the heating and cooling systems and to conduct a cost analysis of the different variants at an early design stage. Similarly, the operation of the heating and cooling sources (e.g. geothermal probes) can be evaluated through this process to enable balanced operation and avoid

system oversizing. Finally, the operation mode analysis process assists in defining the critical HVAC systems, that should be monitored with sensors through technical monitoring (step 2 and step 3).
The scope of this work includes identifying the multiple properties required for this procedure that can be found in an openBIM project. After identifying the properties, their type and where they can be found within a model, the information retrieval in the BIM environment is streamlined.

Step 2: Technical Monitoring: Definition of target values and functional description
Technical monitoring aims to ensure that the building's mechanical systems function correctly and perform according to plan. In order to successfully carry out technical monitoring during operation, target operating conditions must be defined early in the design process together with the systems' measuring points and their acceptable ranges. Additionally, it is important to determine the metering infrastructure in the schematic design (SD) and design development (DD) phases.
The scope of this work includes creating guidelines to simplify the process of including the above key elements in the openBIM project. Additionally, the guideline aims to clarify how the information can be automatically transferred between parties.

Step 3: Technical Monitoring: functional check during operation
The next step in technical monitoring includes data collection and transmission followed by corrective actions. To achieve this objective, the project must guarantee the transmission of collected data to an external monitoring service provider, who evaluates whether the target values are achieved. The results are usually documented in a report that presents the deviations from the target values and indicates the possible causes or deficiencies. Support is later provided for the correction of deficiencies followed by another performance review.
The scope of this work includes defining and digitizing the process of data collection, deviation detection, and carrying out corrective actions.

OpenBIM use case "Dynamic simulation in early planning phase with IDA ICE"
A successful import of a BIM model into IDA ICE is rare. Most BIM models are either not readable by IDA ICE or are imported missing key elements and being partially corrupted. Therefore, this work aims to provide a well-defined framework that specifies how a BIM model should be created to enable a smooth import into IDA ICE. Through a better understanding of the interface between BIM and IDA ICE, this work will provide a use-case that can be applied to streamline the transfer of information from openBIM to IDA ICE (e.g., geometry, materials, and orientation).

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CONFERENCE TOPIC

Digitalization for Future Energy Systems

METHODOLOGY FOR 5TH GENERATION DISTRICT HEATING AND COOLING NETWORK SIMULATION

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SUMMARY

Keywords: 5GDHC, District heating, District cooling, Heat pumps.
The present work aims at developing a numerical model of a 5th generation district heating and cooling network (5GDHC, Buffa et al., 2019). Two different models are co-simulated. On the one hand, the primary mass flow rate in each substation is obtained thanks to a COP estimation (temperature-dependant) and the demand (hot and cold) of the consumers. On the other hand, the network is simulated by imposing the primary mass flow rate in the substations. The present work analyses the interaction between these two models. Finally, optimization potential regarding levels of temperature and distributed hydraulic pump operation is underlined using a sensitivity analysis.

INTRODUCTION

Figure 1 presents the virtual district here considered, which is composed of 10 substations and a main plant. The 5GDHC network is of the 'bidirectional' type with respect to Sommer et al. (2022) and is thus composed of a cold pipe (in blue) and a hot pipe (in red). The hot and cold demand of each building is obtained thanks to the nPro tool (Wirtz, 2023). Each substation has its own valve-pump pair (represented by the blue item 'P' on the Figure) to impose the mass flow rate and a heat exchanger (yellow item 'H' on the Figure).

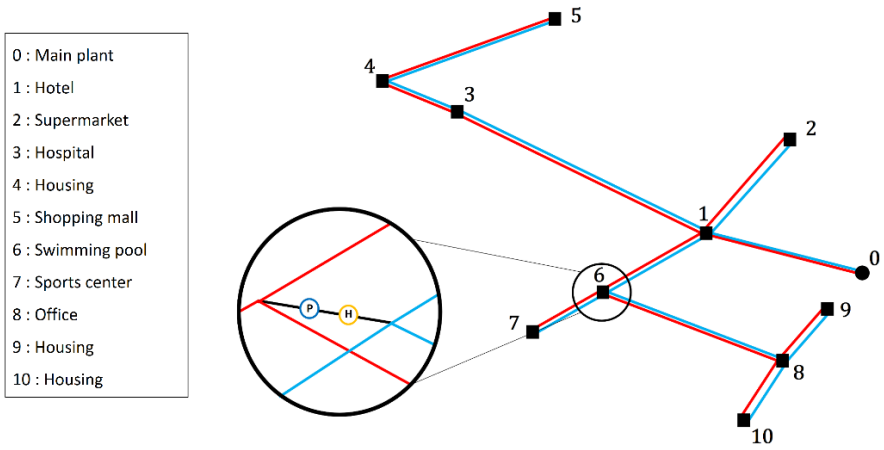

Fig. 1: Architecture of the network.

SUBSTATION

The architecture of the substation is similar to Wirtz et al. (2020) or Abugabbara et al. (2021). A chiller delivers the space cooling and a heat pump delivers Domestic Hot Water (DHW) and space heating. There is a partial balance occurring locally at the substation between the heat pump evaporator and the chiller condenser. The remaining stream is balanced using the network.

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NETWORK

The tool DistrictLab-H (Bavière et al., 2023) is used for the network thermal-hydraulic simulation. Pipes are discretized and the software computes the temperature and the pressure in each element of pipe. The flexibility of the software allows us to easily test different architectures: pressurization of the cold or hot pipe, insulation, meshed network. The primary mass flow rate is imposed in each substation thanks to the substation model (see section 3). Energy is also extracted/rejected from/to the network using the partial balance at the substation.

COUPLING BETWEEN BOTH MODELS

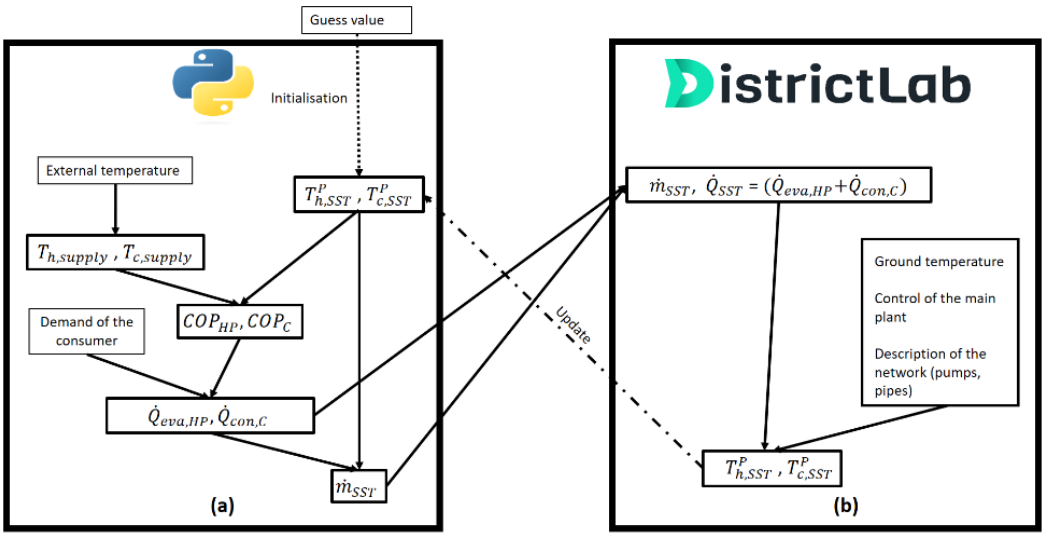

Fig. 2: Principles of the coupling between the substation's model (a) and the network's model (b).

As shown in Figure 2, both models are coupled. A python script launches alternatively the substation model and the network model. Starting from a guessed value of temperature at the cold side $T^P_{c,SST}$ and hot side of the substation $T^P_{h,SST}$ (primary side), the substation model calculates the primary mass flow rates. The latter are then sent to the network model, which calculates the entire pressure and temperature field in the network, thus updating the substation primary side temperatures. An interesting aspect of the present work is an analysis of the convergence process between these 2 models, a topic not addressed in the literature. The main problems for the convergence occur when the pipes are not insulated and/or the plant does not impose the temperature (free-floating mode).

APPLICATIONS

Thanks to the developed coupled model, a sensitivity analysis can be performed in order to highlight optimal temperature and pressure levels. Further work will address the operational control optimization of such network using the analysis of the simulation results.

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CONFERENCE TOPIC

We are applying to the category Future District Heating and Cooling Technologies.

IMPROVING THE ENERGY EFFICIENCY OF A LAUNDRY WASHING MACHINE THROUGH DRAIN-WATER WASTE HEAT RECOVERY

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SUMMARY

This study presents the use of waste heat recovery to improve the energy efficiency of a domestic laundry washing machine. The main objective of this study is to design and fabricate a waste heat recovery unit for a laundry washing machine in order to preheat incoming water and thus reduce the heating load for the washing machine. Initial experiments on a laundry washing machine operating a 60 °C wash cycle have shown that approximately 45 litres of dirty water is drained out of the machine at 48 °C per wash cycle. The amount of heat energy that is lost with this drain water has been calculated to be more than 4300 kJ when assuming that the room temperature of the water is 25 °C. It is expected that the heat recovery unit will recover some of this lost heat and consequently improve the overall energy efficiency of the washing machine. Reducing the energy demand of appliances via waste heat recovery can significantly contribute towards the development of net-zero carbon homes in the future.

Keywords: Waste Heat Recovery; Energy Efficiency; Laundry Washing Machine.

INTRODUCTION

Energy conservation and energy sustainability and its impact on climate change is a topic that is globally known, and much research has been conducted to improve energy efficiency in all areas. A significant amount of energy used for heating domestic water continues to be lost through the drainage system from various sources such as showers, baths, and dishwashers. Recovering this wasted heat from domestic wastewater flows has been proven to be an effective way to enhance the energy efficiency of the household. According to Maediana-Idayu (2012), the phrase "heat recovery" refers to an air-to-air/ fluid-to-fluid heat or energy recovery system that operates between two sources at differing temperatures. In other words, it relies on reclaiming waste heat to warm entering fluid, hence reducing heating loads. There are various types of heat recovery systems available to transfer waste heat (energy) from the stale fluid to the incoming fluid. However, sensible heat recovery systems and enthalpy heat recovery systems are the two basic categories into which all those heat recovery systems often fall.

Washing machines have evolved significantly in terms of design, functionality, and energy efficiency over the years. However, despite these advancements, a substantial amount of energy is still lost during the washing process primarily through the wastewater for high-temperature wash cycles. The waste heat can be recovered to reduce the energy demand as shown by the studies of Wong (2010) who installed a single pass counter-flow heat exchanger beneath shower drains in a residential building and ultimately reduced energy consumption by 4-15% annually. Similarly, studies by De Paepe et al. (2003) resulted in a 25% reduction in total heating demand for the dishwater after incorporating waste heat recovery.

DESIGN OF A HEAT RECOVERY SYSTEM FOR A DOMESTIC LAUNDRY WASHING MACHINE

FABRICATION AND TESTING OF THE HEAT RECOVERY SYSTEM USING AN EXISTING LAUNDRY WASHING MACHINE

RESULTS AND ANALYSIS

CONCLUSIONS AND RECOMMENDATIONS

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CONFERENCE TOPIC

Excess Heat Energy and Resource Recovery from Low-Grade Sources.

SOLAR COGENERATION OF INDUSTRIAL HEAT AND POWER BY A CONCENTRATING HYBRID COLLECTOR

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SUMMARY

This manuscript will present the current status of developing a concentrating PVT collector based on a Fresnel mirror field. The main aim of this development is to provide a future solution for solar cogeneration of industrial heat up to 200°C and electricity simultaneously out of one component, for supporting the enormous energy demand of the industry with renewable sources.

INTRODUCTION

Both commercially available solar energy technologies, photovoltaics (PV) and solar thermal systems (ST), are undoubtably among the key solutions for transforming the global energy supply from a fossil history into a sustainable future. Especially, the combination of PV and ST into a PVT or hybrid collector appears to become rising importance within the solar energy branch, as illustrated by the very positive development of the global PVT market in recent years (Weiss and Spörk-Dür, 2023). Up to now, conventional PVT collectors are limited in terms of possible output temperatures, and therefore, their application is restricted to supply residential heat and power demand so far. On the other hand, industrial consumers require huge amounts of energy, both electrical and thermal. As two thirds of the industrial heat is demanded at temperatures above 100°C (HeatRoadmapEurope, 2017), it is meaningful to apply concentrating solar systems for supporting the industry with solar energy.
The University of Applied Sciences Upper Austria has been working on the development of a concentrating PVT collector (CPVT) for several years. The manuscript proposed by this abstract will provide the current status of the project. It will give detailed insights into the optical and electrical modelling and will cover the performed investigation of a novel heat transfer fluid. Finally, the resulting design of the CPVT receiver will be presented and explained in detail.

THE APPROACH OF SPECTRAL SPLITTING

Conventional PVT collectors necessarily need good thermal coupling between the electrical and the thermal part, which leads to similar temperatures in the PV cells and in the heat transfer fluid. By contrast, such a thermal coupling must be avoided for CPVT systems that shall deliver output temperatures of up to 200°C, as the PV cells would not withstand this temperature. The approach of “Spectral Splitting” can provide a solution for this fundamental discrepancy of CPVT collectors. With this method, the incident concentrated solar irradiance is split into several ranges of wavelengths. The PV part only receives such a spectral bandwidth where the spectral response of the applied semiconductor technology reaches maximum values, whereas all other parts of the spectrum are directly converted into heat (Resch and Höller, 2023b).

OPTICAL AND ELECTRICAL MODELLING

Due to the novelty of the applied concept of Spectral Splitting, comprehensive modelling was necessary for a successful design phase and the subsequent experimental validation. The optical modelling was done for the Fresnel mirror field with a mirror surface of 11 m² that serves as concentrator for the present research work. The

main outputs of the optical model developed in MATLAB are the resulting irradiance in the receiver input plane and the total radiant flux impinging the receiver, among others (Resch and Höller, 2023a). The electrical model was also programmed in MATLAB and fully covers the effect of Spectral Splitting on the conversion efficiency of three different types of PV cells, depending on the setup of the optical filter providing the bandwidth selection (Resch and Höller, 2021).

INVESTIGATION OF A NOVEL HEAT TRANSFER FLUID

The spectrum of the concentrated incident irradiance is split into sections by a combination of a solid and a liquid filter part, where the liquid filter is coincident with the heat transfer fluid. This dual function of the fluid results in manifold requirements in terms of optical, thermal and hydraulic properties. Based on former research work in this field, Triethylenglycol could be identified as a novel heat transfer fluid suitable for this specific application, as extensive material investigation has revealed (Resch *et al.*, 2021).

DESIGN OF A CPVT RECEIVER

Based on the results of the developed models and the performed material investigation, the concept phase of designing a novel CPVT receiver yielded a final proposal of a compact construction, as illustrated in Figure 1. Detailed explanation of the receiver design will be part of the full manuscript.

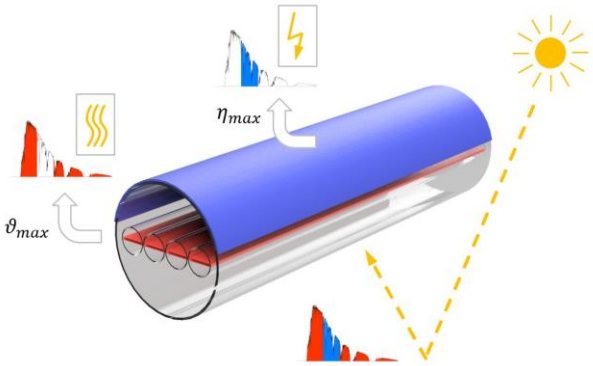

Fig. 1: Illustration of the developed CPVT receiver design (Resch and Höller, 2023b)

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CONFERENCE TOPIC

"Renewable heating and cooling, including high temperature applications"

HOW CAN NON-INTRUSIVE LOAD MONITORING CONTRIBUTE TO THE ASSESSMENT OF THE SMART READINESS INDICATOR?

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SUMMARY

The Smart Readiness Indicator (SRI) is a framework introduced by the EU in 2018 to assess smart buildings in various aspects. The SRI has been criticized for several limitations including its ambiguous service definitions. This paper proposes the application of Non-Intrusive-Load Monitoring (NILM) technology to enhance SRI evaluation on the example of SRI service E12. NILM can be used to disaggregate energy consumption data to end use levels and allows for granular non-intrusive energy consumption measurement. The study involves a rigorous methodology using open sensor data and NILM algorithms to evaluate device-specific energy consumption. Preliminary results reveal trade-offs between data acquisition effort and disaggregation performance, depending on metering frequency. The findings aim to improve the robustness and reliability of SRI assessments by introducing refined measurement and data processing guidelines.
Keywords: Smart Readiness Indicator, Non-Intrusive-Load Monitoring, smart meters, energy consumption

INTRODUCTION

The European Union introduced the concept of the Smart Readiness Indicator (SRI) in 2018 to raise awareness for three key functionalities of smart buildings: occupant-centric control, grid flexibility and energy optimization (EPBD, 2018). The SRI is a framework that covers nine technical domains and standardizes the evaluation of a buildings' readiness to achieve the core objectives. Electricity, as one of the domains, is evaluated based on criteria such as monitoring of energy consumption or application of sensors. The SRI has been the subject of various critiques in academic and policy literature, mainly because it (a) insufficiently considers building typologies and system types (Apostolopoulos et al., 2022; Plienaitis et al., 2023), (b) lacks integration of the building and it's technology into districts and cities (Märzinger & Österreicher, 2020; Plienaitis et al., 2023), (c) contains abstract service level definitions (Ożadowicz, 2022), and (d) focuses on the design outcomes rather than the real impact of the technology installed on the energy consumption in a building (Offermann et al., 2022). Critique is paramount considering the fact that Information and Communication Technology (ICT) that could reduce the energy consumption also requires resources such as electricity (Aretz et al., 2022; Lange et al., 2020). Admittedly, "smarter" buildings do not automatically lead to better buildings considering energy optimization, grid flexibility or occupant-centric control. In addition, the SRI does not provide sufficient guidelines on technical requirements for each specific level and the gained benefits. For instance, often besides hardware also software can be used to achieve significant increases of the SRI score (Varsami & Burman, 2021).
Addressing that, this research delves into complementing the SRI evaluation criteria, by reviewing the challenges associated with data collection and its availability for the SRI, emphasizing the importance of clear data requirements. It highlights the need for standardized data reporting and integration mechanisms, promoting data transparency and reliability. We achieve this by discussing an SRI service in detail and providing arguments and alternatives within a broader scope, considering arguments and requirements from different perspectives such ecological, system integration and data privacy. For this, we discuss several options on implementing the SRI and demonstrate the achieved potential effects by using Non-Intrusive-Load Monitoring (NILM). This paper

evaluates the SRI Service E-12 “Feedback – Reporting Information - Reporting information regarding electricity consumption” which has the precondition “Always to be assessed”.

NILM is a technology that enables non-intrusive measurement of individual end uses of a measurement point through algorithms. This allows for the identification and tracking of device usage, without individual measurements. As a result, device-specific feedback on usage behavior and consumption can be provided. Such direct feedback can lead to up to 12 percent energy savings compared to no feedback on electricity consumption (Carrie Armel et al., 2013). Considering the efficacy of NILM and the current limitation of SRI, we intend to explore how NILM can contribute to the assessment of the SRI.

First, we pre-process sensor data from IDEAL data set (Pullinger et al., 2021) and resample their resolution (15 min, 1 hour). The resampled data are subsequently divided into training and testing datasets. Second, several NILM algorithms from the NILTMK Library (Batra et al., 2014; Shastri & Batra, 2021) are applied to identify energy consumption of devices within the selected households. Models are constructed, calibrated, and validated. Third, disaggregation evaluation metrics are defined, which are then computed for each device and resolution within each household. Last, based on the technical analysis, we identify metering factors that can impact electricity end use identification, and discuss how the data functionalities levels of SRI should be refined, e.g., regarding the term “real-time”.

Our preliminary results provide insights on the trade-offs between disaggregation performance and metering frequency, which impacts the effort for data acquisition and processing. As an example, Fig. 1 visualizes the variation of disaggregation performances depending on the input data frequency and the selected algorithm. With a higher frequency (15 min), the disaggregated energy consumption time series (a fridge from home 73) using both algorithm RNN and algorithm Seq2Seq can fit the fluctuation and magnitude of the resampled ground truth time series better. A more in-depth investigation of disaggregation performance (including evaluation metrics such as Mean Absolute Error) with varying sampling frequencies for multiple devices across households is being conducted. This will be the basis of our further discussion on applying NILM to complement the assessment of the SRI in a full paper.

Fig. 1: Comparison of different disaggregation results using two resampled time series of a fridge from home 73 in the IDEAL dataset (zoomed to Mar. 7, 2018). Time series of the ground truth data (measurement data, resampled to 15 minutes and 1 hour) are shown in solid red color, whereas the disaggregated results using resampled total home consumption data are displayed in dash lines, with RNN in blue and Seq2Seq in green, respectively. Different frequencies are considered as “real-time”.

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CONFERENCE TOPIC

Solutions for Energy Efficiency, IT Technologies and Artificial Intelligence, Smart Services and System Operation, Digitalization for Future Energy Systems

IMPACT OF BUILDING RENOVATION AND REDENSIFICATION ON THE HEATING ENERGY DEMAND OF DISTRICTS

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SUMMARY

The energy-efficient renovation of buildings as well as the provision of further living space in urban areas is an increasingly important topic. However, the effects on existing infrastructures such as the district heating system and the resulting potentials (e.g. redensification) of such development plans are often not sufficiently taken into account. For this reason, this study analyses the effects and potentials of various renovation and redensification scenarios using a newly developed UBEM approach. In this UBEM approach, the existing residential buildings in a selected area are categorised into archetypes based on the data from the energy performance certificate database and then simulated for the entire area. This allows heat load profiles to be calculated for entire urban districts. This method can be used to analyse the potential of foreseeable future scenarios in terms of renovation and redensification with regard to existing infrastructure systems.

INTRODUCTION

Due to the current climate and energy crisis, the European Commission has set ambitious targets for energy efficiency and renewable energy. A large share of the energy consumption can be traced back to the building sector. For this reason, the increase of the renovation rate in the European Union is a key parameter for the implementation of the strategies and the achievement of the targets set by the European Commission. According to the document “A Renovation Wave for Europe” (European Commission, 2020), the current weighted annual rate of energy renovations is only around 1 %. One of the targets in this regard is to at least double the annual rate of energy renovations of residential and non-residential buildings by the year 2030. However, these planned renovations will impact existing infrastructure systems in the respective areas. In order to assess the impact of changes in the building stock on the existing energy infrastructure, the energy demand must be considered integrally at the city or state level rather than just at the building level, leading to an increasingly important method of urban building energy modelling (UBEM).

MAIN SECTION

Therefore, this study aims to investigate the impact of energy efficient renovations and redensifications of residential buildings on the district heating infrastructure. Building renovations can reduce the energy consumption of existing residential areas, allowing for redensification within the capacity of the existing district heating infrastructure. The calculations are carried out using a recently developed UBEM approach (Heidenthaler et al, 2023), which represents the investigated area by simulating detailed physical building models in IDA ICE using predefined archetypes. The investigations are based on the building stock of a test area in Salzburg. For this purpose, building data from the energy performance certificate database in Salzburg is used to create archetypes (Heidenthaler et al, 2022), each of the existing buildings in the test area is assigned to one of the archetypes and simulated for the area in its current state. Afterwards, simulations of scenarios for renovations (average renovations according to energy certificates) and redensification are carried out.

Fig. 1 shows the hourly heat load profile of the test area for the four scenarios in 2018 and for a selected winter week in detail. It can be seen that redensification is only associated with a minor increase in heating load and that renovations can result in a significant reduction in peak loads.

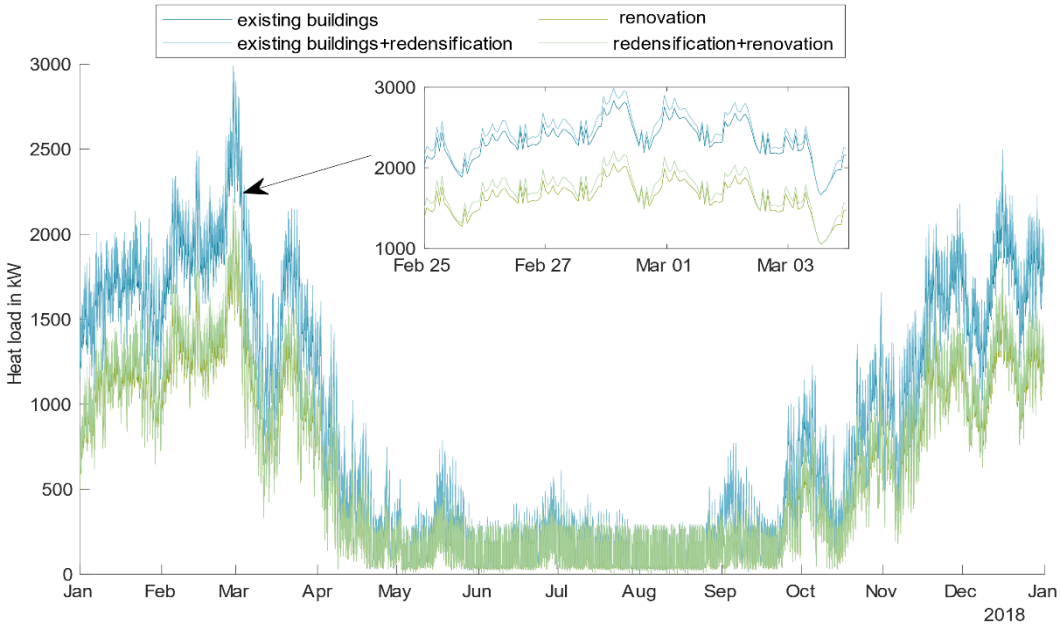

Fig. 1: Hourly heat load profile of the four scenarios for the test area in 2018 and for a selected winter week

The redensification, which in this case would mean additional living space of approx. 6000 m², causes an increase of the heating energy demand (only heat, auxiliary energy and electricity were not considered for this study) by 3.9 %, the renovation can achieve a reduction of the heating energy demand by 31 % (see Fig. 2).

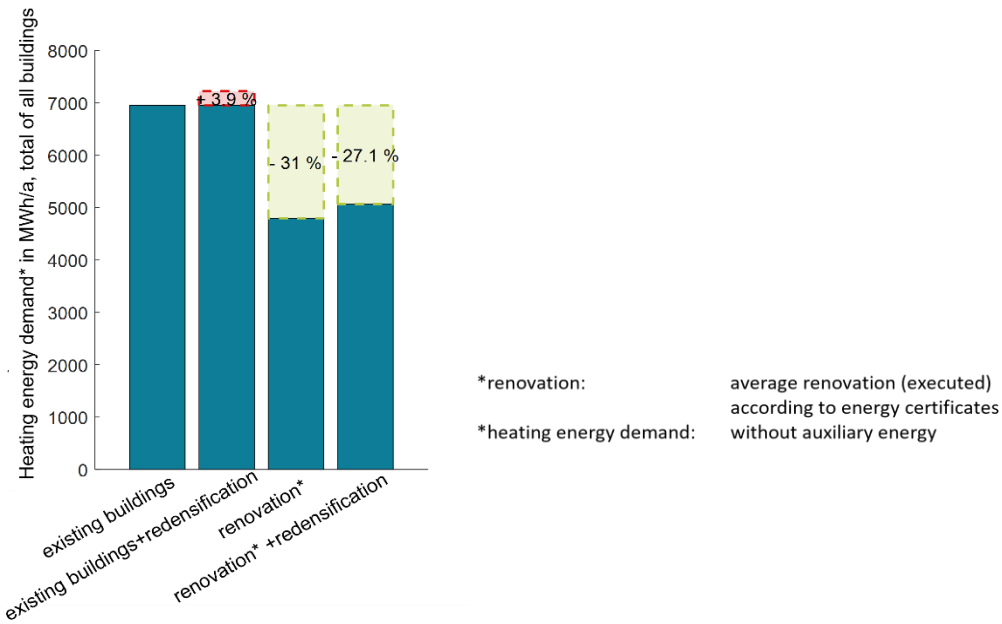

Fig. 2: Heating energy demand of the test area for the base scenarios in 2018

This renovation scenario does not represent optimal renovation of the highest thermal standard, but corresponds to an average renovation recorded in the energy performance certificate data. In reality, higher savings potential can be expected with the corresponding effort, as shown, for example, by the model renovations initiated by the Climate and Energy Fund, with a reduction in the heating requirement of by 82 % on average (Klima- und Energiefonds, 2018).

In order to further investigate this potential, simulations with different renovation standards, considering high thermal renovation standards, will be carried out in the next step.

This automated UBEM approach allows to simulate future scenarios for inner development and their impact on the energy demand of a district.

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CONFERENCE TOPIC

- Solutions for Energy Efficiency
- Sustainable Renovation
- Future District Heating and Cooling Technologies
- Spatial Energy Planning

MODELING TOOLKIT FOR OPTIMIZED DESIGN AND INTEGRATION OF LARGE-SCALE HEAT STORES

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SUMMARY

Large-scale underground thermal energy storage systems offer the flexibility needed to store large amounts of renewable energy to bridge the natural gap between supply and demand. However, to exploit the full potential of this technology, numerical simulations are required along the whole design process.
Hence, we have developed the LargeTESModelingToolkit (LargeTESmtk), a novel Modelica-based toolkit for the modeling and simulation of large-scale pit and tank thermal energy storage. This first comprehensive Modelica library in the field provides the flexibility and tools needed to develop new storage models tailored to the desired application. It also offers researchers and industrial users pre-built storage models for simulation studies to answer the relevant questions for an optimized design at storage and system level.
At the conference, we present the toolkits' main features and the validation of the models. Moreover, we show the application of the toolkit with an exemplary simulation case study and with insights into ongoing projects.

INTRODUCTION

The integration of large-scale underground thermal energy storage (TES) systems offers a high potential to massively increase the share of renewable energy in our future energy systems. They can provide the flexibility needed to store volatile renewable energy sources for a few days as well as on a seasonal basis, bridging the natural gap between supply and demand [1]. At the same time, they also offer a high economic attractiveness for storing large amounts of heat due to economies of scale and a certain flexibility in site selection due to attractive underground integration without free-standing tall structures. In contrast, the large volumes involved lead to high investment costs, which require fundamental planning from the component to the system level. Experimental investigations in the design phase are limited due to the size of these storage technologies and the long time periods in question. Therefore, numerical simulations are used throughout the whole design process [2].
However, currently available models are still scattered, limited in functionality and flexibility (e.g., in the choice of geometries), focused on specific applications, or have not yet undergone a comprehensive validation process. Hence, we have developed the LargeTESModelingToolkit (LargeTESmtk), a comprehensive Modelica-based toolkit for the modeling and simulation of large-scale pit and tank TES [3]. In addition to an easy-to-use Modelica library with scientifically proven, pre-built storage models for researchers and industrial users, the toolkit is also intended to provide the foundation and tools for the development of new storage models customized to the wanted application.

MAIN FEATURES AND MODELS

Fig. 1 provides an overview of the LargeTESmtk. Displayed in the centre is the basic structure of each storage model, consisting of the two main models for the fluid and ground domain, surrounded by an extract of available model configuration options. Along with other features, the library should provide a wide range of configuration options in terms of geometry (e.g., cylindrical, conical, or hybrid geometries), heat transfer mechanisms (e.g.,

pure convection or combined convection and radiation) or ground properties (e.g., uniform ground or specific ground layers) that can be tailored specifically to the wanted application and level of detail. Fig. 2 shows the top-level structure and selected sub-packages of the corresponding Modelica library of the toolkit.

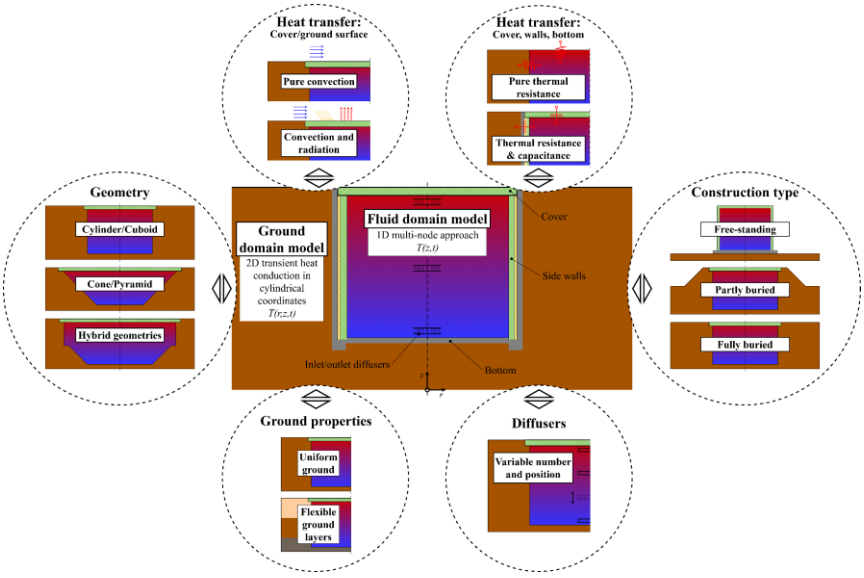

Fig. 1: Overview and features of the LargeTESmtk [3].

Fig. 2: Modelica library structure [3].

VALIDATION OF THE MODELS

To validate and assess the accuracy of the developed tank TES model, a validation case study was conducted comparing the simulation results with real measurement data of the Danish pit TES in Dronninglund [4]. Furthermore, the tank TES model of the LargeTESmtk was part of a cross-comparison study of various large-scale TES models from different simulation tools (e.g., COMSOL Multiphysics, TRNSYS) in a scenario with generic boundary conditions [5]. Recently, as part of IEA ES TCP Task 39 "Large Thermal Energy Storages for District Heating", a comprehensive cross-comparison study with models from various simulation tools including the tank and pit TES models of the LargeTESmtk under standardized test procedures was conducted [6].
Overall, a good agreement between the LargeTESmtk models, the measurement data and the other models could be demonstrated. Further validation studies (including further comparisons with measurement data from real TES systems) are in progress.

APPLICATION OF THE MODELS

The developed models with the LargeTESmtk are to be applied in parameter studies, sensitivity and techno-economic analyses for optimized design on storage and system level. This may include addressing important storage design questions regarding the volume, geometry, insulation quality of the cover, side walls, and bottom, or the number and position of inlets and outlets (i.e., diffusers). In addition, for instance, the investigation of long-term effects (e.g., the development of storage performance in the first years of operation during the heat-up of the surrounding ground) of different system integration concepts (e.g., post-heating concepts via large heat pumps) or storage operation strategies is possible.
At the conference, we are going to demonstrate the application of the library models through an exemplary simulation case study on storage level [3]. The study compares the performance of tank and pit TES with cylindrical and conical fluid geometry under different operation modes ranging from short-term to seasonal storage operation. Fig. 3 shows the used models and the resulting annual storage efficiencies of the simulation case study.

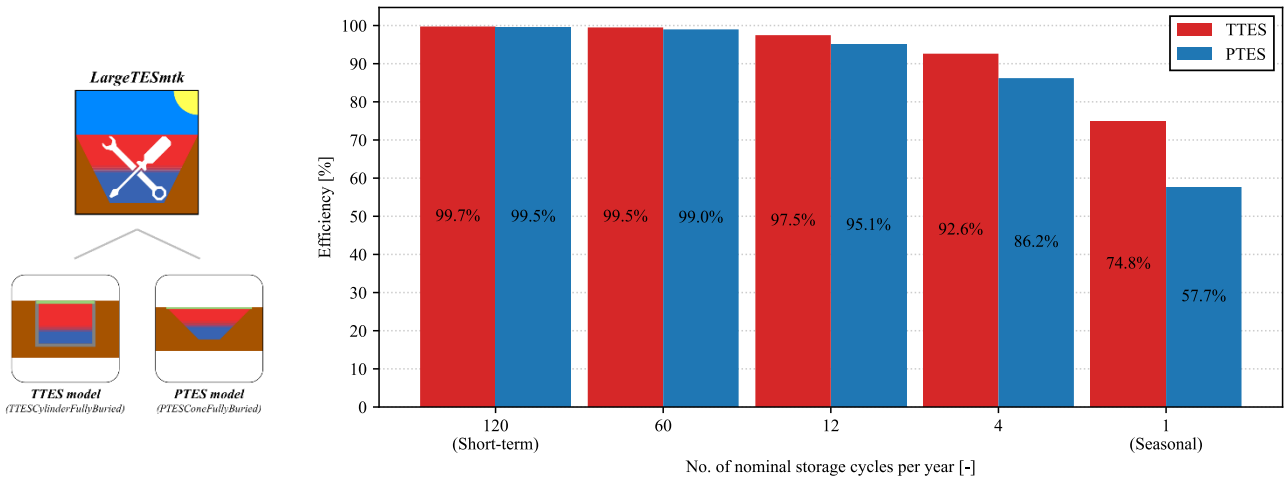

Fig. 3: Used models and annual storage efficiencies ranging from short-term to seasonal storage operation of the case simulation case study [3].

Furthermore, the application of LargeTESmtk models in ongoing feasibility studies and research projects will be shown at the conference.

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

Emerging heat and cold storage

(Future District Heating and Cooling Technologies, Flexibility and Stability of Thermal and Electric Grids)

THE SUNBELTCHILLER – A SOLARTHERMAL COOLING SYSTEM FOR THE SUNBELT

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SUMMARY

We present the SunBeltChiller – a solarthermal cooling system for the sunbelt. It consists of concentrating solar thermal collectors (e.g. Fresnel) and an innovative multi-stage absorption chiller. The smart combination of the absorption cycle with standard water heat and cold storages allow for a high efficient cold production despite high outside Sunbelt temperatures and allow for the use of waterless dry recoolers.
In this paper we present the concept of the energy system and a method based on a geographic information system (GIS) method to identify promising locations and applications for the system. We evaluate the energetic performance of the system in promising locations and in terms of economics compared to reference systems and alternative renewable heating and cooling options like PV driven systems. We show that the SunBeltChiller system is able to facilitate an economically viable significant reduction of carbon dioxide emissions.

INTRODUCTION

The Sunbelt is located between 40 degrees north and south latitude and naturally has a high cooling requirement with high solar irradiation and is therefore predestined for the use of solar-powered cooling systems.
There are two different ways of solar cooling: solar thermally driven sorption chillers or photovoltaic driven compression chillers. A major challenge for all (solar) cooling systems are the ambient temperatures and the associated re-cooling conditions. The higher the re-cooling temperature, the lower the efficiency of a compression chiller or the lower the cooling capacity of an absorption chiller. If the re-cooling temperature is too high, the absorption chiller can no longer be operated. The usually high outside temperatures during the day (>30 °C) require the use of wet cooling towers for the operation of solar thermal cooling systems (absorption chillers).
However, this is often not possible due to water shortages or high humidity. As a result, the use of solar thermal cooling systems in the Sunbelt has been significantly inhibited to date. For this reason, we developed the SunBeltChiller (SBC) specifically for use in the Sunbelt. It does not require a wet cooling tower and consists of commercially available components.

SYSTEM DESCRIPTION

The SunBeltChiller system is driven by heat from concentrating solar collectors at temperatures of about 160° C. In the first step, the solar collectors drive a so-called Double Lift (DL) absorption cooling cycle whose waste heat can be rejected at very high temperatures (approx. 90° C). In the second step, this waste heat from the DL cycle drives a "classic" single effect (SE) absorption cycle which is then re-cooled to the ambience. Due to the use of the two-stage generation of cold and by using standard water based heat and cold storages the operation of the Single Effect cycle can be shifted to the evening or night hours and thus to periods with lower outside temperatures. The overall efficiency (COP) of these two cycles combined - which can be facilitated in one single machine - is equivalent to a high efficient Double Effect (DE) absorption chiller. This eliminates the need for a wet cooling tower. In addition, the SunBeltChiller system can provide additional heat for heating purposes at around 90° C (see scheme in Fig. 12).

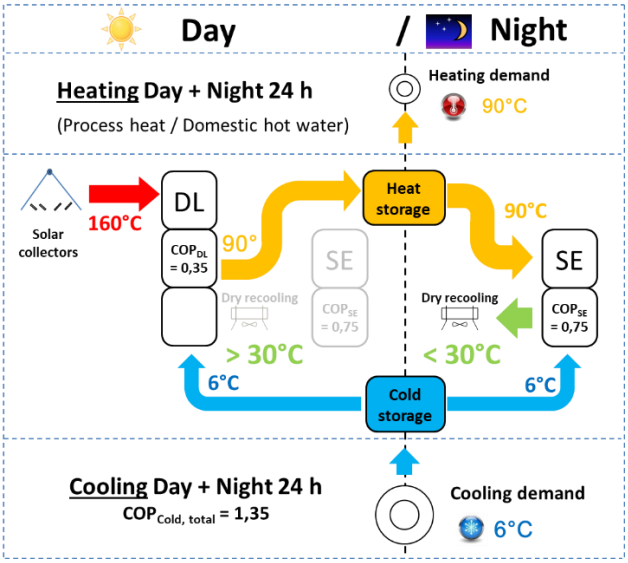

Fig. 12 System scheme of the SunBeltChiller

CASE STUDY RESULTS ON ENERGETIC AND ECONOMIC PERFORMANCE

Within the research a new method to identify suitable and promising geographic locations for the SunBeltChiller has been developed. It makes use of a geographic information system (GIS) where data and information on climatic and economic conditions needed for the evaluation of solar cooling options on a 10x10 km raster can be combined. For example, high solar irradiation, high outside temperatures, water shortage, the presence of industry and financial strength (expressed by GDP) could be indicators for the suitability of the SunBeltChiller system. A promising location in this manner has been identified as Winhoek in Namibia where a typical industry process has benn selected. This industry process (eg. dairy) has a specific time-dependant demand of process heat (160°C), cold and electricity. For this exemplary application – capacity class 1.000 kW – we show the results of a case study where we evaluated the energetic and economic performance of the system compared to a (fossil based) reference system and alternative renewable solar heating and cooling options (like PV). The results come from a design and evaluation tool, which has been developed within this research work. The results show that the SunBeltChiller system facilitates very high reduction of CO_2 emissions with still attractive economic and financial feasibility. Consequently, we give recommendations for the reasonable application scenarios for this innovative system concept.

ACKNOWLEDGEMENTS

This work could be realized within of the ongoing research project “Solar thermal energy system for cooling and process heating in the sunbelt region – SunBeltChiller (SBC)”. The project is carried out by two partners: Industrial Solar GmbH and the Bavarian Centre for Applied Energy Research (ZAE Bayern). It is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) (grant number 03ETW026).

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CONFERENCE TOPICS

Renewable heating and cooling, including high temperature applications, Solutions for Energy Efficiency, Future District Heating and Cooling Technologies

LIFE CYCLE ASSESSMENT OF FIFTH-GENERATION DISTRICT HEATING AND COOLING SYSTEMS: TOWARDS SUSTAINABLE URBAN ENERGY SOLUTIONS

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SUMMARY

Fifth-generation district heating and cooling systems (5GDHC) represents a promising solution to address the growing energy demands of urban areas while minimizing their environmental footprint. The technology combines advanced district heating and cooling infrastructure with renewable energy sources, enabling efficient and environmentally friendly energy distribution. This study proposes a framework to evaluate the environmental impacts associated with the entire life cycle of 5GDHC systems, including often overlooked embodied emissions. The findings of this study not only contribute to a better understanding of the sustainability of 5GDHC systems but also provide valuable insights for policymakers, urban planners, and energy professionals seeking innovative solutions to meet the challenges of urbanization and climate change. Ultimately, this research aims to promote the adoption of 5GDHC as a sustainable and economically viable urban energy solution, fostering a transition towards more resilient and eco-friendly urban environments.

INTRODUCTION

Fifth-generation district heating and cooling (5GDHC) systems are seen as a solution to decarbonise the heating and cooling sector (Buffa et al. 2019, Kristian Gjoka et al. 2023) and previous research (Gjoka et al. 2024) confirms their viability in terms of cost and operational emissions reductions. However, existing literature lacks a comprehensive life cycle assessment, particularly in assessing embodied emissions. Our study introduces a novel framework, bridging this gap and exploring 5GDHC's potential in mild climates with heightened cooling demands. This groundbreaking approach contributes to sustainable energy system design, emphasizing flexibility under diverse electricity tariffs and grid emissions.

RESEARCH METHOD

Our multi-dimensional assessment framework focuses on Engineering, Economic, and Environmental (3Es) performance for energy master planning. Combining quantitative and qualitative metrics, it evaluates engineering performance through electricity import and operational flexibility, economic performance via total annualized cost, and environmental performance utilizing a holistic life cycle approach, including embodied emissions. Demonstrating the framework through a case study of a new university campus in Melbourne, Australia, we compare a 5GDHC system with a state-of-the-art business-as-usual system see Fig. 13.

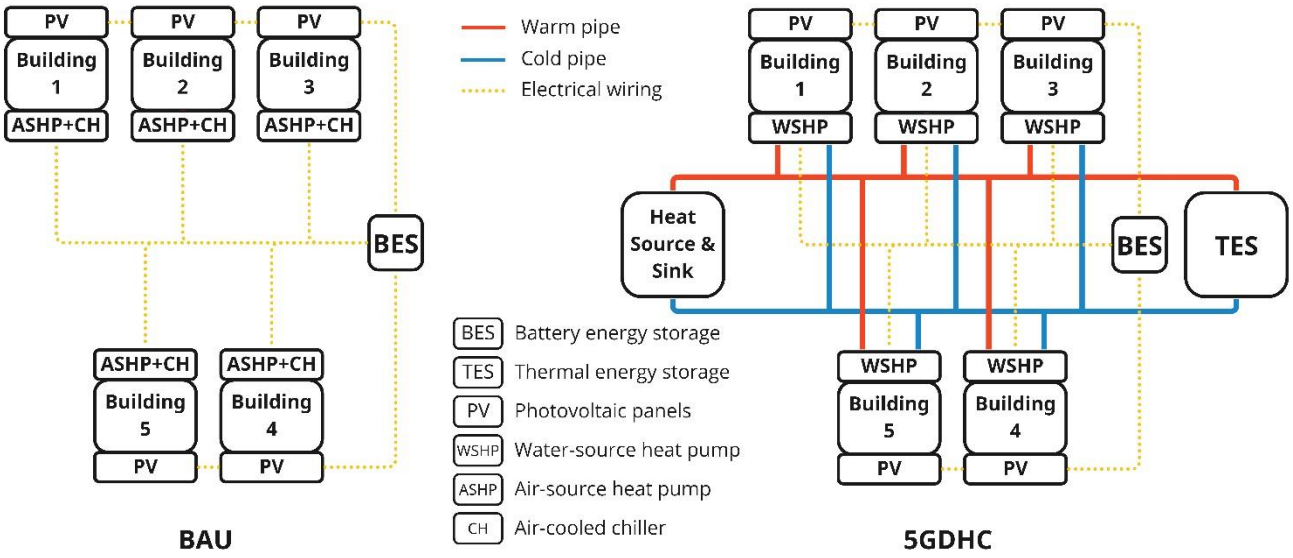

Fig. 13 Schematic representation of the business-as-usual and 5GDHC systems studied.

DISCUSSION

A multi-dimensional assessment framework for 5GDHC was developed and tested in a new context by comparing a 5GDHC solution against a state-of-the-art business-as-usual system. The framework proved valuable for energy system planning and showed that, in the analysed context, 5GDHC solutions can significantly reduce heating and cooling costs and greenhouse gas emissions reductions through energy sharing and efficient use of local heat sources and sinks. Moreover, the flexibility 5GDHC offers through a smart use of thermal storage can open new opportunities for sector coupling with the power grid. Sensitivity and scenario analyses confirmed robust results. While limited to early-stage assessments, the framework offers valuable insights for 5GDHC system adoption in Australia and other similar contexts.

CONFERENCE TOPIC

This abstract refers to the topic of Future District Heating and Cooling Technologies combined with the overarching theme of Life Cycle Assessment.

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SOLAR RENAISSANCE THROUGH ENERGY ENTITLEMENT: ENERGISING MULTI-OWNED BUILDINGS WITH SUITABLE ENERGY ALLOCATION PRINCIPLE

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SUMMARY

Adoption of Renewable Energy Systems (RES) in Multi-Owned Buildings is menial compared to detached homes. The joint ownership of the RES in Common Properties (CP) develops disagreement over the space function, per-unit investment, liabilities, and benefit allocations. This study aims to overcome this barrier by introducing a novel concept, the 'Energy Entitlement', that encapsulates the energy ownership and land administration aspects by delineating the ownership of energy to the apartment residents, inclusive of electricity and thermal energy. The current energy allocation principles, if any in practice, are based on localised agreements among the residents and lack a legislative structure, often leading to disputes. A standardised decision-making framework is proposed in this study, encompassing the attributes of multi-owned buildings, that acts as a guiding tool for the owners' corporations, policymakers, and industries in choosing the optimal allocation principle of energy generated from the solar panels installed in the common properties of multi-owned buildings.

INTRODUCTION

The developmental goals have ascended greenhouse gas emissions compared to the pre-industrial levels. The irregular climate patterns put immense pressure on the district heating systems, and power grids. The decentralisation of renewable energy systems is gaining momentum to alleviate the dependency on a centralised system (Kaundinya et al., 2009) and to enhance the energy security of the communities, especially in dense urban areas. However, the spatial limitation in the city impedes this overarching goal, eventually hurting the globally accepted environmental ambitions. Thus, a paradigm shift of focus has emerged, with an enhancing emphasis on the building rooftops to either satisfy the self-consumption of energy or as a base for virtual power plants.

The exponential growth of the urban population resulted in mushrooming multi-owned buildings (MOBs), that accommodate multi-cultural families commonly sharing the building facilities (Poshnath et al., 2023), including the RES. However, the rooftops in MOBs are predominantly deemed the common property of the building that the residents jointly own and governed through the formation of 'Owners' Corporations'. The common ownership often results in disagreements over energy usage for electricity, heating and cooling, per-apartment allocation, and sharing benefits. The lack of a regulatory standard for energy allocation resulted in the inferior adoption rate of RES in MOBs compared to detached homes, depriving apartment residents of the benefits of renewable energy and essentially hurting the environment.

The work critically focuses on the underdeveloped realm of energy allocation from a commonly owned renewable energy system in a multi-owned building. A few studies recommend allocating the generated energy equally (Syed et al., 2020) or based on investment (Akter et al., 2019). However, these recommendations do not consider the characteristics of each energy allocation principle and the ownership perspective. This study established a novel concept of 'Energy Entitlement', which delineates the share of renewable energy each apartment can utilise, focusing on equitable allocation. Energy entitlement facilitates the incorporation of policy and regulatory aspects, acting as a ground for resolution of renewable energy disputes. Figure 1 illustrates the concept of energy entitlement in a MOB.

Though the actions toward renewable energy harnessing are boosting globally, the legislations often overlook the complexities associated with the joint ownership of common properties. Though recommendations are present for the sub-division of common costs and entitlement, the focus on renewable energy allocation scarcely exists.

The Victorian Current Acts state that '*lot entitlement in the plan must be allocated on the basis of the market value of the lot and the proportion that value bears to the total market value of the lots',* while 'lot liability' should be allocated equally between the lots unless there is significant variation in size of the lots, usage of common properties, or the number of occupants. However, these principles do not account for the dynamic attributes of energy that vary with respect to the building typology and per-apartment characteristics. Moreover, each of these allocation principles grants different energy entitlement to each apartment, emphasising the necessity of choosing the most suitable energy allocation principle that incorporates the characteristics of the building for the smooth functioning of the community. A case study of an MOB with ten apartment units have been conducted and Figure 2 illustrates the variation of energy entitlement based on the allocation principles suggested by legislation.

Moreover, it is indeed essential to analyse the performance of other potential energy allocation principles. This work presents a holistic framework, encapsulating the unique attributes of distinct multi-owned buildings to choose the optimal energy allocation principle, irrespective of electricity or thermal energy. The inherent risk of each allocation principle is determined by conducting a dispute analysis of the registered relevant cases. The framework provides the ranked list of suitable energy allocation models and can act as a guiding tool for the stakeholders. The proposed framework is expected to promote pro-environmental behaviour, the monetisation of surplus energy, and reduce grid dependency, assisting in achieving the net-zero objectives.

FIGURES

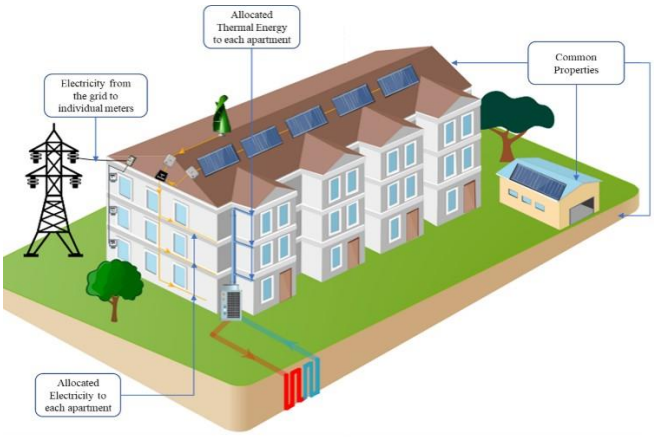

Fig. 1: Energy Entitlement Concept (Poshnath et al., 2023)

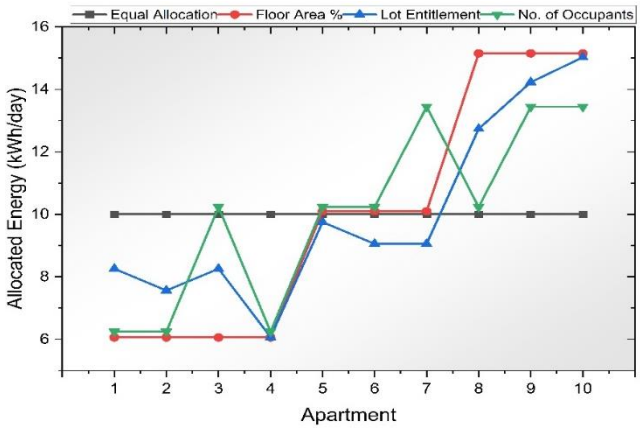

Fig. 2: Variation of Energy Entitlement in a MOB

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CONFERENCE TOPIC

Solutions for Energy Efficiency; Policies; Spatial Energy Planning

REPLACING FOSSIL-FUELED COMBINED HEAT AND POWER PLANTS WITH MALTA'S PUMPED HEAT ENERGY STORAGE TECHNOLOGY TO PROVIDE CLEAN POWER AND DISTRICT HEAT

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SUMMARY

This paper analyses the potential integration of a 100 MW_{el} 10-hour Malta Pumped Heat Energy Storage (PHES) system into the district heating network of the city of Hamburg, Germany, using otherwise curtailed energy from an offshore windfarm located near the city for charging. It is shown that this configuration can avoid the curtailment of 227 GWh_{el} of wind energy per year. The system could provide 117 GWh_{el} of electricity to the grid in times when less renewables are available, as well as 72 GWh_{th} of thermal energy for Hamburg's district heating network. Compared to the coal-fired combined heat and power (CHP) plant that shall be replaced, this system could reduce the annual CO_2 emissions by 101,400 tonnes.

INTRODUCTION

To reach the EU climate and energy targets and objectives set in the European Climate Laws, ambitious targets on the build-out of renewables together with a phase-out of coal have been established by the EU. The transition from fossil-fueled to renewable electricity generation impacts not only the power sector, but also the decarbonization of the heat sector. The retirement of coal power plants, among them many that are operated in a CHP mode to supply heat for district heating, and the electrification and increased build-out of district heating systems using renewable heat will require the implementation of new, innovative technologies. One of the technical solutions that provides flexible power and heat is Malta's Pumped Heat Energy Storage (PHES).
There are many locations in Germany with high installed onshore and offshore wind capacity, e.g. in the states of Schleswig-Holstein and Lower Saxony, where not all of the available renewable electricity can be transmitted to consumers on windy days due to the lack of grid capacity. In these cases, wind turbines have to be curtailed. In 2020, 5,820 TWh of renewable energy were already curtailed across Germany [1]. This figure will continue to rise in the future with the increasing expansion of renewables. This curtailed energy could be used to charge a Malta M100 PHES system in the city of Hamburg, which comprises a large district heating network. For our example, we take a large CHP plant in Hamburg, which is still using hard coal for the time being, but shall switch to more sustainable energy sources by 2030. This paper studies the integration of a 36-hour 100 MW Malta PHES system ("M100") storing only otherwise curtailed wind energy into Hamburg's district heating system, providing 24/7 green heat as well as green power in times of low wind energy availability to the city of Hamburg.

TECHNICAL CONCEPT TO PROVIDE GREEN HEAT FOR DISTRICT HEATING

Malta's PHES technology, also called M100, is a long duration energy storage system of 100 MW net AC synchronous discharge power designed to meet grid-scale energy storage needs for various market applications. This product brings stability and resiliency to the grid by alleviating load mismatch between demand and generation and providing grid services, such as frequency and voltage control, rotating inertia and short circuit current. It uses molten salt and a coolant to store variable renewable energy that has been converted to thermal energy (heat and cold) through the Charge Heat Pump, and reconverts it into dispatchable synchronous power and process heat, through the Discharge Heat Engine, as illustrated in Fig. 1**Fehler! Verweisquelle konnte nicht**

gefunden werden.. Malta PHES fully replaces conventional gas-fired power plants and CHP plants. With its temperature range from 115°C supply to 15°C
return, the process heat discharged from the Malta PHES technology can be used for heating applications at a district level or in industrial processes. If the whole temperature range is used, up to 70 MW_{th} of heat can be extracted at the Discharge Heat Heat Exchanger (DHHX) at full rated condition. Additional storage and backup heating are options to ensure covering a 24/7 heat delivery.

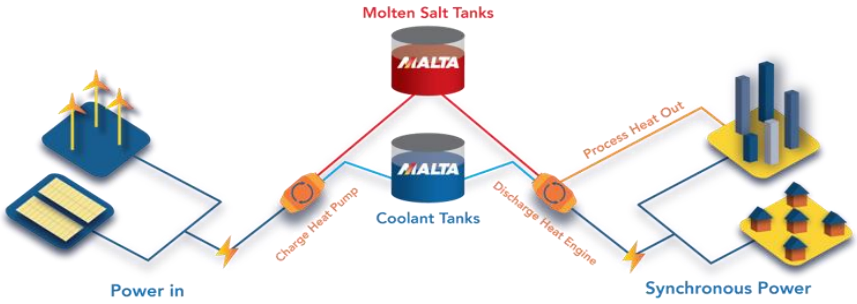

Fig. 14: Conceptual Diagram of the Malta Charge and Discharge Sequence

APPLICATION EXAMPLE

For this study, the curtailment instructions (German: Einspeisemanagement) for the offshore wind farm "Borkum West 2" of the year 2020 were considered as a typical year for reference. The system was simulated in Malta's proprietary detailed thermodynamical hourly performance model. The wind farm is curtailed for 1440 hours [2], out of which 1195 hours could be used to charge the chosen 36-hour storage system. As can be seen in Fig. 2, most curtailment occurs in winter between November and March, matching very well the Hamburg district heating heat demand curve. A total of 227 GWh_{el} of otherwise curtailed wind energy could be stored. 117 GWh_{el} would be returned to the electricity grid, while 72 GWh_{th} of thermal energy could be used in the district heating network. The overall energy losses result in 39 GWh. As this energy storage plant would replace a coal-fired power plant, the CO_2 reduction results in 101,400 t per year. The paper also analyzes which parts of the existing power plant (e.g. transformers) could be repurposed and integrated into the Malta M100 plant.

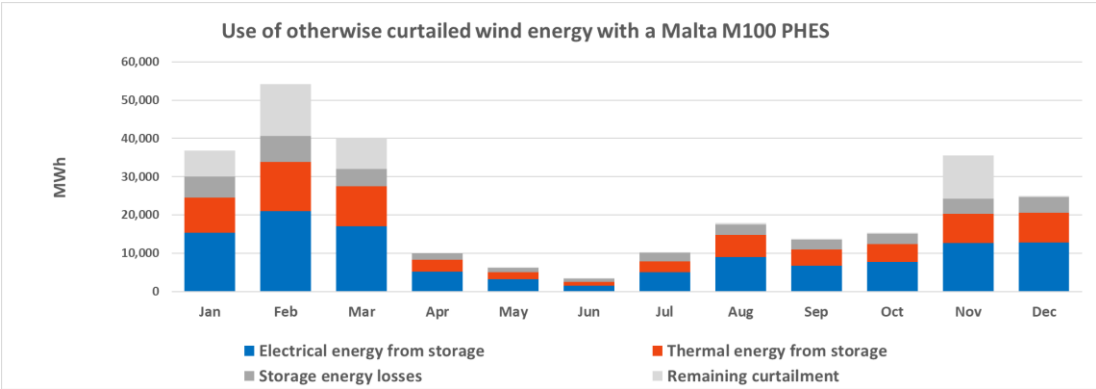

Fig. 15: Monthly distribution of otherwise curtailed wind energy stored in the Malta M100 PHES system

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CONFERENCE TOPIC

Replacement of big fossil Power Plants by Renewables – Impact on District Heating

SUPPORTING A FAST IMPLEMENTATION OF LOW-GRADE RENEWABLE ENERGY AND WASTE HEAT FOR DISTRICT HEATING AND COOLING

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INTRODUCTION

At present district heating and cooling (DHC) contributes around 12% of the final energy consumption for space heating and hot water with about 25% of the heat supply from renewable energy sources (RES)[15] and a large remaining part still from fossil fuels, often coal and natural gas. Higher rates of RES have been so far only achieved in countries such as Sweden, Denmark, Austria, Estonia, Lithuania, Latvia and Iceland. However, in almost all current long-term studies, the transformation of the DHC sector is identified as one of the central keys to the urban heat transition and thus to the overall goal of a carbon-neutral Europe by 2050[16]. To fulfil this role, extensive technical DHC measures are necessary, ranging from the conversion of heat generation to renewable and climate-neutral energy sources to the expansion, densification, and modernization of DHC. For the desired transformation of the DHC sector, necessary investments totalling to about 600 B.€ are estimated[17].

THE CHALLENGE

In the next three decades, the implementation of required measures will be particularly challenging for owners and operators of DHC systems and all related stakeholders, such as authorities, involved in this process. The main challenges are (1) the necessary investments in the DHC infrastructure and related implementation efforts itself are enormous (2) the upcoming definition for energy efficient DHC in Article 24 of the EED revision will define a clear roadmap until 2050 and thus requires a holistic transformation planning of DHC operators for decarbonizing their DHC systems in line with the EED, and (3) technologies such as low-grade renewable energies (RE) and waste heat (WH) are new to many operators and create the need of technical support to many subprocesses of DHC transformation and investment planning. Thus, the overall objective of the SUPPORT DHC project is to address these challenges by supporting a fast implementation of low-grade renewable energy and waste heat for DHC in Europe.

THE SUPPORT DHC PROJECT

The overall objective of the SUPPORT DHC project (co-funded by the LIFE Programme of the European Union; contract no. 101119914) is to support a fast implementation of low-grade renewable energy (RE) and waste heat (WH) for district heating and cooling (DHC) in Europe. This is achieved by supporting DHC operators in drawing-up transformation plans leading to efficient DHC systems as defined in the Energy Efficiency Directive revision and in particular concrete investment plans for a fast implementation of packages of low-grade RE and WH measures. In six European countries (AT, DE, IT, LT, PL, UA), the SUPPORT DHC project in cooperation with involved DHC operators demonstrates such processes and leads to investments on the ground for a variety of EU-wide DHC system cases.

[15] European Commission: „District Heating and Cooling in the European Union: Overview of Markets and Regulatory Frameworks under the Revised Renewable Energy Directive“, 2021, https://energy.ec.europa.eu/district-heating-and-cooling-european-union_en
[16] https://climate.ec.europa.eu/eu-action/european-green-deal/european-climate-law_en
[17] District heating investment to reach Heat Roadmap Europe 2050 Scenario, IEA, 2020

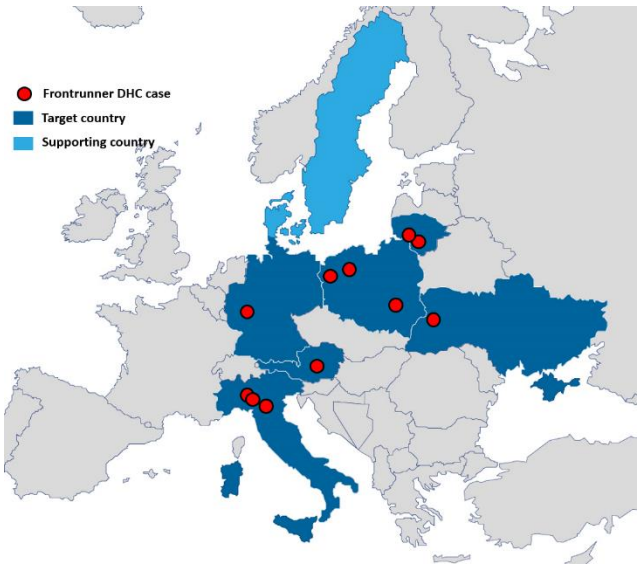

Fig. 1: Geographical focus of SUPPORT DHC

The support of DHC operators is rolled-out through a 3-step approach, as shown below:

1. Extensive support is provided to 11 DHC frontrunner cases,
2. minimum 27 follower cases are selected during the project and supported, and
3. more than 100 DHC operators are reached by replicating support services also in countries beyond the SUPPORT DHC target countries.

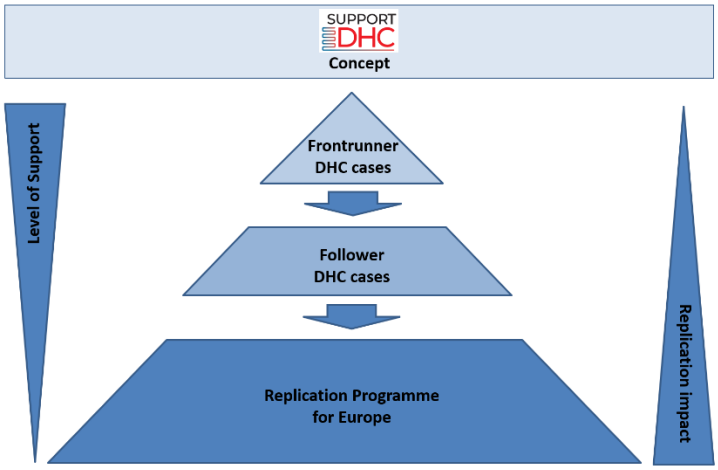

Fig. 2: 3-step approach of SUPPORT DHC

The project further aims at capacity building of DHC operators for managing and steering such processes and of the specific service providers and other stakeholders for supporting transformation and investment planning. At policy and regulatory level, local and regional authorities will become enablers of transformation measures as the project addresses solutions for removing barriers and framework shortcomings. Furthermore, also at national and EU levels, market and framework barriers and solutions will be identified and fed into the political decision-making processes. Know-how gained in the SUPPORT DHC project will be disseminated to further EU DHC markets and replication will be actively organised.

CONFERENCE TOPIC

Future District Heating and Cooling Technologies
Policies
Spatial Energy Planning

Co-funded by the European Union

TRANSFORMATION OF LARGE DISTRICT HEATING AND COOLING SYSTEMS TO HIGHER SHARES OF RENEWABLE ENERGY SOURCES

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SUMMARY

In many countries, DHC systems based on renewable energy and waste heat sources are considered as major solution for climate change mitigation in the heating and cooling sector. In order to facilitate the transformation of existing DHC systems and to support their operators and other branch stakeholders with the necessary knowledge and methodologies, the R&D work of IEA DHC TS5 addresses following key challenges:

- Harnessing RES technologies for DHC systems
- Methodologies for assessing the local potentials of RES DHC
- Transformation of DHC as a holistic long-term process with technical and organizational challenges
- Decentral integration of RES DHC generation in DHC systems
- Organizational and non-technical aspects of DHC transformation processes

The general approach of IEA DHC Annex TS5 is to upgrade existing RES DHC knowledge to international level, to develop a common base and understanding and to promote its use in the national markets.
This abstract highlights the work and results of Subtask B "Transformation of large DHC systems to higher shares of RES" such as a collection of bottlenecks and key enablers for implementing RES and transformation guidelines

INTRODUCTION

The International Energy Agency District Heating and Cooling Task-shared Annex (IEA DHC TS5) aims for gaining knowledge about and develop enhanced solutions for the technical and operational integration of Renewable Energy Sources (RES) plants into existing traditional and modern District Heating and Cooling (DHC) systems. Furthermore the project partners want to provide practical knowledge on RES DHC project development, technical solutions and business cases to the DHC market actors. Another goal is to develop, and show-case innovative demo cases driven by DHC market actors and in cooperation with RES market actors (for both, technical and organizational solutions) and develop advanced instruments addressing non-technical market barriers and opportunities such as the demo cases from Graz and Aalborg.
Last but not least the TS5 wants to get renewable heat sources in place as environmentally friendly and emission free heat generation technologies for the DHC sector.

METHODICAL APPROACH

The work focused on the development of a categorization and evaluation matrix of for large DHC system transformation cases (categories and criteria may include starting point and actual status, system size, share of RES, climate conditions, etc.) This led to an in-depth analysis of case studies as input for the development of transformation guidelines.
As another outcome a collection of best-practices and methods in planning and simulation could be found

The IEA DHC TS5 Subtask B aims for

- Provide practical knowledge on RES DHC project development, technical solutions and business cases to the DHC market actors
- Develop and show-case innovative demo cases driven by DHC market actors and in cooperation with RES market actors (for both, technical and organizational solutions)

addressing all stakeholders along the value chain.

TRANSFORMATION GUIDELINES

The main objective of these guidelines is to provide guidance to transformation processes towards 100% RES in DHC. This happens by delivering high-level / hands-on recommendations.
The developed transformation guidelines for large-scale DHC systems are meant to be a variety of guidelines for different starting points and boundary conditions since there has to be a separate Transformation plan of every DHC System.
Potential key enablers and pitfalls in the transformation pathway are also highlighted to keep stakeholders addressed aware of them.
Finally it is planned to evaluate the guidelines on real pilot studies.

EXAMPLES FROM THE CASE STUDIES

One of the eight case studies comes from the City of Graz DH system. Graz already transformed very well towards a higher RES share until 2023 as can be seen in Figure 2. The DH supply has changed its RES share from 6% in 2013 to 23% by 2018 and there is a keen plan with implementations of further RES already started.

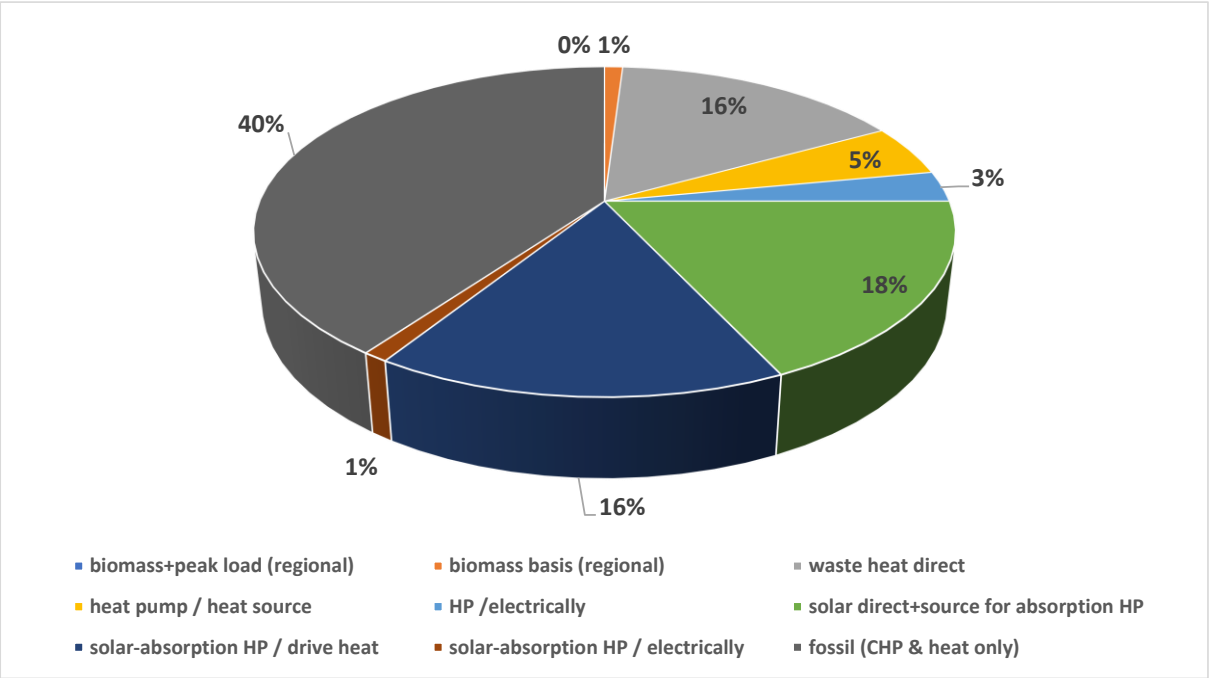

Figure 43: Planning of district heating supply mix for the Graz region 2023-2028 renewable: 40 % drive heat of heat pump, electricity: 20 %; combined heat and power and boiler heat: 40 %. Source: Grazer Energie Agentur / Stadt Graz Umweltamt

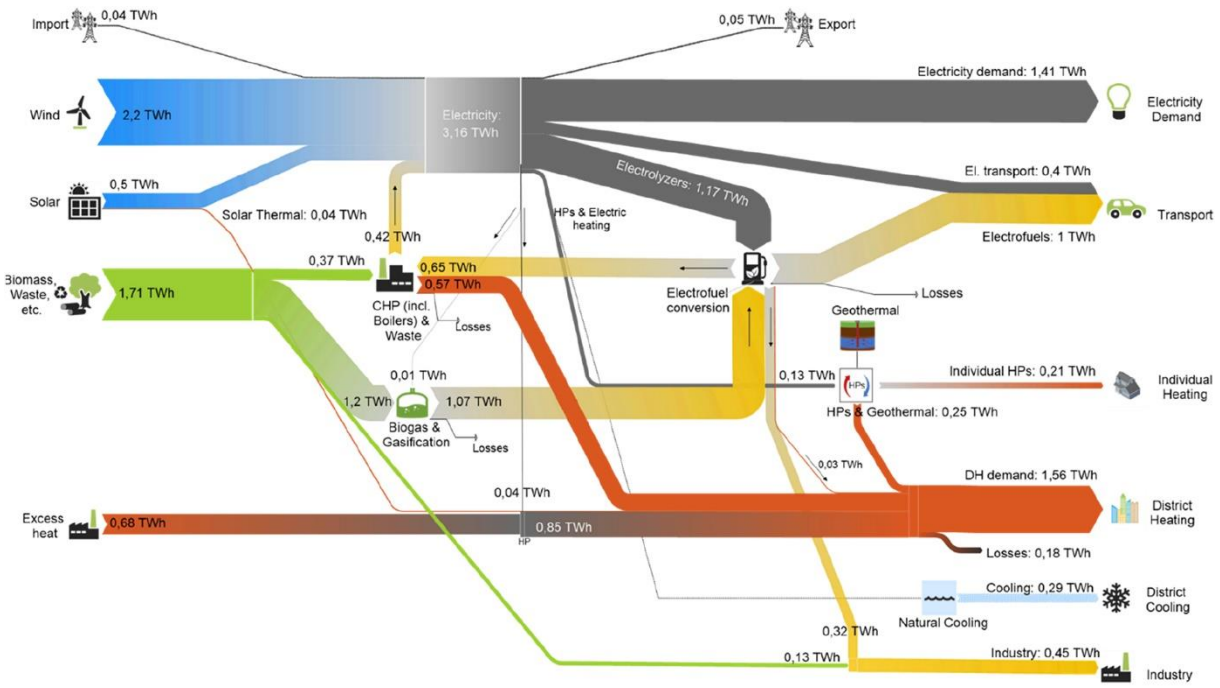

Figure 44: Sankey diagram of Aalborg's (Denmark) energy system in 2050 based on the results of the EnergyPLAN simulation of the 2050 scenario. The diagram of the case study shows the yearly input of primary energy and how it is used in various conversion technologies to supply the energy demands. Source: Aalborg University

For the specific case of Aalborg Municipality, Denmark a case study has been contributed where the energy system effects of going from a 3GDH system to a 4GDH system (see Sankey diagram in Figure 1) in a RES-based energy system have been investigated The analyses indicate for the specific case that the uptake of excess heat from industrial processes can be increased from 335 GWh directly and 113 GWh indirectly via HPs with 3GDH to 683 GWh directly and 168 GWh indirectly with 4GDH, where the indirect use requires temperature boosting through HPs.

Grid losses can be reduced from 21% to 15%, not counting effects from energy savings in buildings. The COP of DH HPs can be increased from 2.9 to 3.9. Altogether the total annual energy system costs are found decreased by around 2.7% from 641 M EUR in the 3GDH scenario to 624 M EUR in the 4GDH scenario, and the total primary energy consumption can be reduced by 4.5% going from 3GDH to 4GDH.

REFERENCES

IEA DHC Annex TS5: Integration of Renewable Energy Sources into existing District Heating and Cooling Systems, project website, https://www.iea-dhc.org/2019-2024-annex-ts5

CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Coupling of Energy Sectors
- Flexibility and Stability of Thermal and Electric Grids
  Future District Heating and Cooling Technologies
  Replacement of big fossil Power Plants by Renewables – Impact on District Heating

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INTERMITTENT OPERATIONS OF DISTRICT HEATING NETWORKS IN SUMMER MONTHS: A SHOWCASE

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SUMMARY

In the OREWA project, optimization measures for existing heat networks were identified and assessed based on both economic and ecological considerations [1]. One of the focal investigations was the simulation of intermittent operational strategies tailored for the summer months. Next to the classic intermittent approach an innovative variation was explored, which involved the introduction of cold water during intermediate phases to further minimize heat losses. Both the classic and innovative intermittent strategies showcased substantial reductions in network losses and energy consumption for circulation pumps. Furthermore, when households already possess buffer tanks with capacities from 600 to 1000 liters, the implementation of these optimization measures yields economically viable results, with payback periods of less than 10 years. This research enhances the efficiency of heat networks with 80 % summer heat losses and a low heat demand density of 0.7 MWh/(m²·a).

Keywords: Heating network, optimization, intermittent operational strategy, reduction of operational costs

INTRODUCTION

In the context of the intermittent operational approach, a temporary shutdown of the circulation pump was simulated, enabling the natural cooling of the pipe network while ensuring customers continue to receive hot water from decentralized buffer tanks. Within the OREWA project, the viability of implementing this approach was assessed in a case study for the existing heat network of Effelter, Germany. The heat network, exclusively serving single-family homes with summer domestic hot water needs, was modelled in MATLAB/Simscape, validated with measurement data, and combined with two different control strategies (see Table 1) aiming to minimize heat network losses and pump electricity consumption.

Table 1: Control strategies for optimized summer operation of heating network in Effelter

Base	Continuous operation of heating network.
Classic intermittent	Charging of decentralized storages at customer; subsequent turn-off from network pump; natural cool down of network.
Innovative intermittent	Instead of the natural cool down with "*Classic intermittent*" the water within the pipe network is exchanged with cold water to further minimize heat losses.

STATE OF THE ART

The intermittent operational strategy, involving temporary shutdowns of circulation pumps and the use of buffer tanks, aims to reduce heat network temperatures. Several studies, including [2] and [3], have explored this strategy. It can yield thermal energy savings ranging from 0.4% to 6%, with payback periods typically exceeding 20 years. An exception can be found within the *heat_portfolio* project following the innovative intermittent strategy which showed a 13-year payback period, although detailed cost calculations were lacking due to the complexity of implementation. Ref. [4] studied intermittent operation in a *well-insulated heat network* with *diverse users* (which are two of the main differences to OREWA). They assessed daily charging of decentralized storage tanks under two scenarios: one with higher supply temperatures and smaller tanks, and the other with lower supply temperatures and larger tanks. Both scenarios incurred greater losses than continuous operation.

METHOD

To model the heat network behavior Simscape and Carnot within the MATLAB environment were used. The simulations were conducted for a representative week in summer. The load profiles are based on VDI 4655 for domestic hot water demand and scaled according to the number of residents per household. The evaluated relative savings were then compared to continuous operation and dynamic payback periods were calculated.

RESULTS

An initial analysis was done regarding the impact of different supply temperatures (of 80 °C and 90 °C) on the *classic intermittent* operational strategy. Using 90 °C supply temperature facilitated quicker tank heating which led to longer rest periods for the heating network and reduced pump electricity consumption by 40 %. However, the higher network temperature increased heat network losses by 0.4 %. With the assumed energy prices of 60 Euros/MWh_{th} and 0.36 cents/kWh_{el}, the 90 °C supply temperature strategy proved to be more cost-effective.

Consecutively, the study compared the *classic and innovative intermittent* heating strategy with continuous operation (see Table 2). The *classic intermittent* strategy significantly reduced heat network losses by 24 % and electricity consumption by 77 %, saving 1,022 Euros annually. Since the *innovative intermittent* strategy requires more pumping power and can only save 1.6% heat in relation to the *classic intermittent* strategy, the cost saved is only 1,006 Euros annually. However, investing approximately 10,000 Euros for buffer tanks at each house may not justify the measure if they need to be purchased.

Table 2: Comparison of continuous and classic intermittent operation for a summer season

	Supply temperature	Saved heat energy	Saved pump energy demand	Operational cost savings*
Base / Continuous	75 °C			
Classic intermittent	90 °C	14.9 MWh	355 MWh	1.022 €/a
Innovative intermittent	82 °C	15.2 MWh	271 MWh	1.006 €/a

*Heat generation cost 60 €/MWh, electricity cost 0.36 €/kWh

DISCUSSION

The study identified substantial heat loss reduction potential during summer months through intermittent district heating network operation. Furthermore, a decrease in pump electricity consumption was evaluated. These findings offer economic advantages, with a potential eight-year payback period, assuming the control system is the only implementation cost, and existing residential buffer storage can be utilized. However, under different conditions, the suggested operation may not be economically viable.

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CONFERENCE TOPIC

This abstract refers to the Conference Topics “Future District Heating and Cooling Technologies”.

ECONOMIC ROLE OF ENERGY STORAGE TECHNOLOGIES IN AUSTRIA

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SUMMARY

Energy storage technologies are essential for Austria's future energy system, facilitating renewable source integration and enhancing grid stability. The IEA ES Task 41 addresses the challenge of quantifying the economic value of energy storage systems and developing successful business cases. Subtasks A-D focus on methods for economic evaluation, acceptable storage costs, success story documentation, and systematic assessment/business model development. Austria's 2030 targets involve optimizing the overall system, using battery storage for peak load reduction, and exploring seasonal heat storages. Economic value assessments are underway for large-scale thermal energy storages, battery storage systems, and hydrogen storage, highlighting contributions to efficiency, grid stability, and renewable integration. Ongoing R&D projects aim to further develop and apply these economic evaluations for successful energy transformation.

Keywords: energy storage, economic value, flexibility, energy transition

INTRODUCTION AND OBJECTIVES

Energy storage technologies are pivotal for the future energy system, primarily in facilitating the integration of renewable sources. They address the intermittency of renewables by storing excess energy during peak production for later use. This enhances grid stability, smooths out fluctuations in the short run and seasonally, and reduces the need for overcapacity in energy generation. Additionally, energy storage fosters flexibility, enabling rapid responses to changing demand. The decentralized nature of local energy storage supports resilient, independent power and heat generation and the supply of energy carriers as a resource. Overall, these technologies contribute to emission reduction, aiding the transition to a sustainable energy future by minimizing reliance on fossil fuels.

Despite the importance and necessity of the energy transformation, it is difficult to quantify the economic value of an energy storage system and transfer it into successful business case. This challenge is precisely what the IEA ES Task 41 is addressing - by analysing the value of energy storage and deriving potential business models. Subtask A focuses on compiling existing methods and devising new ones for economic evaluation. In Subtask B, the estimation of maximum acceptable energy storage costs is conducted. Subtask C involves documenting and analysing success stories of energy storage systems. Subtask D aims to systematically assess gathered information from Subtasks A-C, creating a framework for evaluating energy storage configurations to establish successful business cases [1]. The anticipated outcomes include methods for assessing economic viability, defining key performance indicators, identifying favorable energy storage configurations, recognizing challenging cases, comparing configurations with other flexibility measures, analyzing regulatory influences, and framing business case development. A national communication strategy of the Austrian project partners ensures knowledge exchange, facilitating the dissemination of international and national findings to stakeholders.

FRAMEWORK CONDITIONS AND PRIORITIES FOR AUSTRIA

In the use of energy storage technologies in Austria, ten targets have been set for 2030, including the optimisation of the overall system through electricity and heat storage, the use of battery storage to reduce peak loads in industry and research into seasonal storage options. Implementation measures include improving the legal framework, ensuring data availability, encouraging new business models, carrying out pilot projects, providing planning tools and offering education and training programmes. [2] In line with Austrian objectives, the consortium is focussing on economic value for thermal energy storage, electrical storage technologies and hydrogen storage.

Economic value of large-scale thermal energy storages

In the implementation of large-scale thermal energy storage systems, it is essential to consider various regional conditions (e.g., urban environment, land availability) and be familiar with suitable construction methods, cover concepts, dual-use possibilities, as well as hydrogeological challenges such as water quality, groundwater flows, and thermal insulation. Additionally, it is necessary to consider regional legal, political, or economic influences to analyze the value for enhancing the efficiency of renewable technologies, assessing savings through increased flexibility, improving the reliability of district heating, and utilizing grid stability through innovative solutions across interacting sectors by deploying thermal energy storage technologies. In ongoing research and development demonstration projects, the aim is to precisely develop these results and make them available for the implementation of the energy transition.

Economic value of compact thermal energy storage

The integration of latent and thermochemical heat storages in existing energy systems, both in industrial heat recovery and domestic buildings, is a challenging act. Both private and industrial sector face uncertainties regarding the cost of storage materials, components, as well as maintenance requirements. Hence, the results from successfully integrated storage applications will be reflected upon and transferred to the concepts of compact storages. Within this task a comprehensive analysis of the economic value of compact storages in the context of industrial processing paths and seasonal applications will be conducted. The results will conclude the boundary conditions in which realistic business models of compact storages are possible.

Economic value of battery storages

Battery storage systems contribute to the renewable energy penetration as they provide flexibility for the electricity sector with a very short response time. Especially in terms of distribution grids, battery storages can be used to facilitate secure, green energy supply by providing systems services. Nowadays, batteries are mainly used to increase the self-sufficiency and self-consumption rate of PV users together with the application of peak shaving to decrease the demand peaks, since both operation modes reflect directly on the energy bill of the individual prosumer. Ongoing research projects focus on the development of additional ancillary service markets (e.g.: phase symmetry, flexibility provision, voltage regulation, etc.), where each battery operator is able to participate together with the system operators in need of those services. In these new market models' remuneration streams for battery storage service provision are in place to incentivise the battery storage integration and thus facilitate an ongoing smooth operation of the electrical power grid, while at the same time transforming the energy supply sector to a greener one.

Economic value of hydrogen storages

Hydrogen is a secondary energy source that appears to be essential for the decarbonization of the energy system, especially due to its role as a long-term storage option and its direct use in industrial processes. For many sectors, there are few or no options for decarbonization other than hydrogen. Long-term storage of energy for electricity production or for peak loads in district heating networks are also expected areas of application. Especially for hydrogen from electrolysis, due to the conversion losses, the focus should be on these areas which have no or

few alternatives. If natural gas is an accepted alternative to hydrogen, the economic viability of electrolysis hydrogen is difficult to demonstrate; in a fully defossilized energy system, hydrogen and its derivatives such as synthetic, renewable methane or ammonia appear to be essential due to the possible amount and duration of storage.

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ACKNOWLEDGEMENT

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CONFERENCE AND CROSS-CUTTING TOPIC

- Emerging heat and cold storage
- Finance and Business Model

MONITORING AND EVALUATION OF THERMOSYPHON AND PV HOT WATER SYSTEMS UNDER THE SAME OPERATING CONDITIONS IN A SIDE-BY-SIDE EXPERIMENTAL SETUP

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SUMMARY

Renewable heating and cooling is amongst the primary focus of the Southern African Renewable Heating and Cooling Training and Demonstration Initiative in creating capacity pertaining to this subject. This emphasis is aligned with the United Nation's 2030 Agenda, which seeks for carbon-neutrality by the year 2030. To address thermal needs on small scale, evacuated tube collectors, thermosyphons, and photovoltaic to heat systems are frequently used. For a scale-up application of these technologies, and for accelerated achievement of carbon-neutrality, a cost-effective technology must be prioritised in various areas of the world with different meteorological conditions. This study therefore intends to establish the technical performance and the cost-effectiveness of these technologies in Namibia's environment.

Key-words: *Solar Water Heating, Thermosyphons, Photovoltaic, Levelised Cost of Energy, Monitoring*

INTRODUCTION AND BACKGROUND

The demand for hot water is increasing globally, and many countries have set targets to encourage a higher fraction of their energy production to come from solar technologies. Through its Solar Thermal Roadmap, Namibia targets to have installed 1 500 000 m^2 of solar thermal collector area by the year 2030 (Shidhika and Iileka, 2018). Two technologies that are expected to play the biggest role in the solar hot water market by 2030 are solar thermal thermosyphon and solar photovoltaic (PV) derived hot water heating systems. These technologies are especially promising for the Sunbelt region (between the 20th and 40th degrees of latitude in the northern and southern hemispheres, where Namibia is located (Weiss and Spörk-Dür, 2023). According to Namibia's Updated Nationally Determined Contributions (NDCs) to curbing climate change, Namibia has a strong focus on avoiding 91% of its greenhouse gases (GHG) emissions by 2030 (Ministry of Environment, Forestry and Tourism, 2021). By targeting mitigation in the energy sector, which is the second largest GHGs emission sector in Namibia, one of the strategies would be to separate heating from fossil fuel-based electricity. This can be done by the implementation of proven solar water heating technologies in place of the traditional boilers and electric water heaters, which are associated with CO_2 emissions.

In doing so, technological solutions should be cost-effective for end users so that the continued utilisation of these technologies is sustainable. To date, data or literature that substantively suggests which solar water heating technology is most cost-effective and suitable for given boundary conditions (e.g., hot water consumption profiles, solar irradiance levels) is scarce. There is a lack of comprehensive comparison studies of thermosyphon and PV hot water systems for household applications under real-life conditions, in particular for Namibia. A comparative study of a flat plate thermosyphon solar water heater and a photovoltaic water heater conducted by

NEI revealed that it is convenient in terms of installation and technical operation to have a photovoltaic water heater over a flat plate thermosyphon solar water heater due to its simplicity (S.Shimhanda, H.Ileka, & F.Shidhika, 2018). This study was however based on actual energy consumption patterns, which were distinct for the two different installations; therefore, the results do not reflect a fair comparison. Furthermore, the study did not extend to the other technology, which is commonly being utilised, the evacuated tube solar water heating technology. Another similar study conducted in South Africa demonstrate that a thermosiphon system is more cost effective (Buckly et al, 2019). Similarly, this technology excluded the evacuated tube collector system, nor it emphasized on technical performance. It is against this background that NUST and NEI, through the Southern African Renewable Heating and Cooling Training and Demonstration Initiative (SOLTRAIN+) and IEA SHC Task 69 intend to undertake this study. The proposed study will provide comprehensive information while addressing the gaps in similar studies. The comparative study will also contribute to IEA SHC Task 69, where the systems design of solar hot water technologies are analyzed and market studies are performed.

EXPERIMENTAL SET-UP AND METHODOLOGY

Three designs are proposed, each unit consisting of a 200 liters tank and collectors/PV modules with 1.2-1.6 kW equivalent nominal thermal power/kW-peak. The three systems are:

- System 1: Indirect thermosyphon system with a flat plate collector;
- System 2: Indirect thermosyphon system with evacuated heat pipe collector; and
- System 3: PV-to-Heat (PV2Heat) system.

The overall objective of this setup is to conduct a side-by-side comparison of small-scale installations for solar-derived hot water. The system will be equipped with a monitoring system that logs all the data pertaining to the performance of the systems, such as hot water temperature and hot water flow rate. Primarily, the hot water temperature profiles within the tanks of the three systems will be analyzed to establish which system produces the most heat and at what cost, and establish the levelised cost of thermal energy (LCOE). The three systems will be installed on a 12m shipping container, with the monitoring system, controls, and the storage tank of the PV2Heat system installed within the container. The container will be erected at the Science and Technovation Park at NUST. The project is currently in the detailed planning phase, with the first components being shipped to the site. The setup is expected to be in operation by January 2024.

EXPECTED OUTCOME

It is expected that there will be no hurdle in monitoring and gathering metrological data as well as the technometrics of the system. Under the SOLTRAIN+ project, NEI has already monitored some domestic small-scale solar water heating systems hence it is a usual experience for the institute. The monitoring system should be able to inform on the ability of these systems to supply hot water for the predetermined water consumption profile that replicates the hot water demand of a small-scale household. By controlling the hot water consumption profile, the experimental setup allows a fair comparison of the three technologies, which was not present in previous work. It will further be established whether the storage tanks are able to retain the heat produced during the day. By having the cost of the components of the system, the LCOE can be established, and it can serve as an indicator of cost-effectiveness. Furthermore, it is planned to perform a detailed life cycle assessment (LCA) of the systems.

CONCLUSION

The study will contribute to NUST's Green Vision of 2030, which aspires to contribute towards a future where all energy is consumed from sustainable sources and sustained by a public that understands and values the social, economic, and environmental benefits that green energy provides to our communities, our nation, and beyond

through an integrated green energy creative value chain. In addition, the study will provide good information to the industry regarding the best systems suitable for the Namibian climatic conditions, considering the economic, environmental and technical performance of the systems. Similarly, the results of the study will support market confidence in the technologies.

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CONFERENCE TOPIC

- Renewable heating and cooling, including high temperature applications
- Life Cycle Assessment
- Special focus on developing countries
- Approaches towards net-zero/negative emissions in the industry including CCU

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THE PIT THERMAL ENERGY STORAGE AS CENTRAL COMPONENT IN FLEXIBLE AND GREEN ENERGY SYSTEMS

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The pit thermal energy storage (PTES) has been the default choice for seasonal storage of heat. Examples include the PTES in Dronninglund and Marstal in Denmark where the PTES was constructed to store the excess heat from solar collectors during summer to use in the winter. For the PTES in Dronninglund a ammonia heat pump was built to utilize the heat in the storage with too low temperature to supply for the district heating consumers.

These thoughts of maximizing the use of the solar collectors sparked the interest in seasonal storages but now there is a change in the landscape. The idea of using the PTES for daily and weekly heat storage is rapidly becoming popular as it enables the district heating companies to easily choose the cheapest source of heat for any given moment and store the produced or excess heat in the PTES. The PTES has become the central component in the district heating systems and provides valuable flexibility and possibilities to lower the cost of heating and cooling. How do we best integrate the PTES into complex district heating systems using the experience and knowledge from seasonal PTES as Dronninglund?

A VEHICLE2GRID INFRASTRUCUTRE SUPPORTING THE LOCAL DISTRIBUTION GRID BASED ON STANDARDIZED COMMUNICATION, FLEXIBILITY PREDICTION AND SIMULATION

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SUMMARY

A shift from fossil fuels to renewable energy sources, with a focus on electromobility, it is one of the goals regarding climate impacts. Austria aims for a 30% increase in electric vehicle (EV) adoption by 2030. However, this transition places added stress on the distribution grid, particularly when EV charging lacks coordination. The Accu4Vehicle&Grid project addresses this challenge by developing a swappable accumulator system, integrated with intelligent management and communication protocols. This innovation aims to leverage parked EV accumulators for renewable energy optimization and grid stabilization, targeting municipal sectors. Smart Grid Architecture Model, communication standards, and real-life testing in a Living Lab define the methodology to achieve its goals, with expected outcomes such as Vehicle2Grid integration, standardized data models, and improved distribution grid operation.

INTRODUCTION AND METHODS

The European Union's ambitious goals regarding climate neutrality impacts the mobility sector in a way, that fossil resources need to be replaced by renewable energy sources, which can be achieved by electro mobility. Following the e-mobility approach, a maximum scenario for Austria expects an 30 % increase of e-vehicles by 2030 [1]. Nevertheless, an increased penetration of e-vehicles also leads to an additional stress on the distribution grid, especially in the case that EV charging takes place in uncoordinated manner, but coordinated by an intelligent grid they could provide a huge bi-directional buffer capacity for a Vehicle2Grid application.
Against the background that many e-vehicles are only parked for a large part of the day and e-commercial vehicles are also unused for many hours of the day, it would be a worthwhile approach to make the accumulators of e-vehicles available as buffer storage for the self-optimization of renewable energy utilization and some ancillary services for stabilization of the distribution grid. Within the project Accu4Vehicle&Grid a linked infrastructure system including a novel swappable and multifunctional accumulator system is developed, which is usable in a mobile and stationary operation. However, the accumulator system, the application of management based on artificial intelligence which is able to control the local energy flows based on the information received from the grid provider, the local energy producers, the tour plans of commercial vehicles, the local energy consumers, and the status of the stationary battery storage; in addition with the utilization and simulation of standard communication protocols towards the distribution grid control center led to an overall innovation considering the vehicle, the grid, and the local energy system [2]. For that, this work focuses on the integration of ancillary services in an advanced

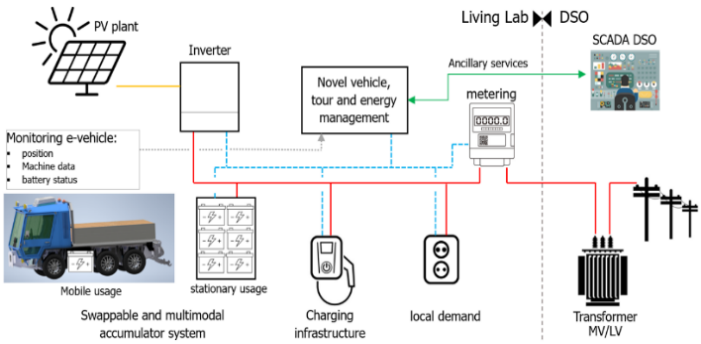

Fig. 3: Concept of the swappable accumulator system and a novel management system providing ancillary grid services.

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distribution grid management by designing processes fit the Vehicle2Grid (V2G) application into the Smart Grid Architecture Model (SGAM) which provides a structured framework for understanding the complex ecosystem of a smart grid and defines functional layers, components, information flows, and communication standards to facilitate the design, implementation, and management of intelligent and efficient electrical grids [3].
In a Living Lab the project innovations are brought together by testing first the single components functionality and further testing addressing the grid-friendly functionality. It includes energy monitoring system, communication interfaces for the EMPA-Trac vehicle, local energy generators and consumers and the grid operator.

EXPECTED RESULTS

In this contribution, we proposed an approach for the integration of a Vehicle2Grid system in future smart grids (SGAM), mainly at the introduction of advanced route and vehicle management, the evaluation of the local energy flow and communication on process, field, and station zone.
Based on statistical analysis methods, tends identification and simulations of historical and real-time energy data and the flexibility of a vehicle accumulator, a novel flexibility profile forecasting is expected to be calculated for a decentralized distribution grid management.
An investigation of standardized communication methods for an improving functionality of Vehicle2Grid in the context of management local distribution grids provides the basis for the establishment of a seamless, interoperable, and data-driven communication infrastructure for data exchange within the vehicle and the distribution grid.
The flexibility profile forecasting and standardized communication methods achieves a resilient data basis for simulating the future status of the local distribution grid by a novel grid control.
Finally, within demo runs the system is expected to be proofed according to its functionality based on Use Cases developed.
The developed Vehicle2Grid system facilitates advanced automation, real-time monitoring, predictive maintenance and, ultimately creating a more adaptive and resilient local distribution grid that can efficiently integrate renewable energy sources and support evolving energy needs.

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CONFERENCE TOPIC

The proposed work addresses the topics “Flexibility and Stability of Thermal and Electric Grids” and “Digitalization for Future Energy Systems”.

SOLAR THERMAL TECHNOLOGY AND GOVERNMENT WORKING TOGETHER TO CUT COSTS AND EMISSIONS AND BOOST SKILLS

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SUMMARY

A solar water-heating installation at the air force base in Hoedspruit has demonstrated improved energy efficiency, cut costs and CO_2 emissions, and left personnel with new skills. A remarkable success story has played out at the Hoedspruit Air Force Base over the past four and a half years with solar technology at its heart. On 1 May 2019, SANEDI and the South African National Defence Force (SANDF) collaboratively commissioned two 1 500-litre solar water-heating systems to keep the bungalows that are home to the base's personnel supplied with hot water. The Solar Thermal Demonstration and Training Initiative (SOLTRAIN) contributed training and 30% of the capital required. Since then, SANEDI and the SANDF have tracked the performance of the system, specifically focusing on electricity and cost savings and translating these into tons of CO_2 emissions avoided. The numbers are nothing short of impressive – and inspirational.

INTRODUCTION

A solar water heating installation at the air force base in Hoedspruit has not only demonstrated improved energy efficiency, and cut electricity costs and CO_2 emissions, but has also acted as a catalyst for upskilling South African National Defence Force (SANDF) personnel.

The South African National Energy Development Institute (SANEDI), the Solar Thermal Demonstration and Training Initiative (SOLTRAIN) and the Department of Defence collaborated in the implementation of the solar water heating (SWH) system at Air Force Base Hoedspruit, Limpopo, South Africa.

On the 1st of May 2019 the South African National Energy Development Institute (SANEDI) and the South African National Defence Force (SANDF) collaboratively commissioned two 1500 litre solar water heating systems for military accommodation bungalows in Hoedspruit, South Africa. This project was supported through training and some financial contribution [30%] of the SOLTRAIN programme. Since the operationalisation of this project, SANEDI and the SANDF have been tracking the performance of this system, specifically focusing on electricity and cost savings and translating these to savings in tonnes of CO_2.

While all involved expected significant cost and electricity savings, no one predicted just how quickly these would be realised. In just over two years, the installation had saved enough in electricity costs to cover the capex of the hardware and associated services. The 841.5MWh that the system had saved by end of September 2023, translates into a cost saving of R1.85 million and 816.2 tons of CO_2 that had not been released into the atmosphere. The two installations are functioning at a solar fraction of 96.8%.

Considering the combined advantages of reduced electricity consumption and costs, artisan upskilling and CO_2 emission reductions, this project has proven to be a good all-round solar thermal solution to integrate previously

un-utilised technology into a government department that strives to be self-sufficient. Not only did the project introduce solar thermal technology benefits and sustainability, it also catalysed an unusual sequence of events serving the industry, the sector and government.

Performance data, in real life situations and challenges, is proving the technology's value and ability to deliver a significant return on investment. More importantly, though, the project made such a powerful case for technology acceptance, skills and capacity development and investment potential, that the SANDF has become an investor in the solar thermal sector in South Africa.

THE NUMBERS AND THE SKILLS

These systems were conceptualised in order to offer warm water security/surety to members of the SANDF staying in bungalows at the Air Force Base. It was foreseen that there would be a significant cost and electrical savings, however what was not foreseen was how quickly this savings would begin to pay off. In just over two years the entire installation had saved enough in electricity costs to cover the capex of the hardware and associated services.

Taking into account the numerical success above, the project's other success story goes beyond statistics, it is important to note that there has been another equally significant contribution from this project. This project has led to the training 107 SANDF artisan members at various levels in solar thermal technologies. The training aspect of this collaborative project ensures that the Defence Force does not become reliant on civil society to maintain the hardware at its bases. It also equips artisans with skills that are in step with changes in the energy landscape and advances in technology, and paves the way for other government entities to instal renewable-energy technologies at a large scale at their facilities.

Having the necessary skills available, has already led the SANDF to invest in a domestic solar-water heating installation at another of its bases to address severe water challenges.

Training and skills development

SANEDI and SOLTRAIN presented a variety of training sessions to introduce renewable energy to the SANDF and upskill military artisans to maintain solar water-heating in-house:

- Thermosyphon system introductory training.
- Mini apprenticeship.
- Quality inspector.
- System calibration and servicing.
- Specialised training for solar-thermal experts and professionals.

Fig. 1 Opening the systems officially in 2019

Fig. 2 Servicing the systems 2021

Fig 3 Systems calibration and Service 2022

CONCLUSIONS

This project has not only introduced solar thermal technology benefits and sustainability, but has also catalysed and unusual sequence of events serving the industry, the sector and government. Data collection on the system proves the technology's value as well as investment return potential, however the intricacies behind motivating support for technology acceptance, skills and capacity development, investment potential and business case development, leading to ultimate reinvestment and growing investment, from the South African National Defence Force into the solar thermal sector in South Africa. This project catalysed a win-win situation for all parties involved and it would appear that the successes sustained herein are leading to bigger and better things to come.

CONFERENCE TOPIC

Renewable heating and cooling, including high temperature applications

RENEWABLE ENERGY CONCEPT FOR AN INDUSTRIAL QUARTER IN TRANSITION

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SUMMARY

The research project InEs creates an innovative energy supply system for a commercial district at the site of the former Bavarian porcelain factory Winterling in Schwarzenbach a.d. Saale. The starting point of the project was the redevelopment of the district with an area of six hectares and a 40,000 m² large factory complex. The objective is to achieve a high renewable share by sector coupling and integration of storage technologies. The waste heat of two existing CHP and an ORC unit is to be used for heating the building through a cellar-integrated storage tank. Organic and silicon photovoltaics as well as the use of wind power have been analysed. A life cycle assessment, which compares the refurbishment of the existing building with a comparable new building, provides information on the sustainability of the continued use of industrial buildings. In addition, legal issues for the energy supply of the tenants are investigated. Three local industrial companies (production of LED street lamps, abrasives and baker's yeast) in the vicinity are involved in the project.

ROOM-INTEGRATED THERMAL ENERGY STORAGE

The biogas for the two CHP is generated in an innovative process during waste water treatment of a nearby yeast factory and is transferred to the Winterling area via a gas pipe. The waste heat of the CHP and an additional ORC unit is already used for heating the Winterling building. Together with the backup gas boiler they sum up to 940 kW_{th}, as only one CHP can run simultaneously. To be able to use an even higher share of the heat, a large hot water storage will be built in a cellar. The new concept, also discussed in (Schiffmann et. al, 2020), uses the walls of the room as the static limits for the storage, see Fig. 1. They will be insulated from the inside and a liner will prevent moisture penetration into the insulation. The room is then flooded and has a water content of 1,240 m³. Different insulations materials such as PU, PIR, glass foam, cork and VIP are investigated. For the liner, PP or stainless steel sheet as well as glass-fiber reinforced plastic are the most promising approaches. CFD simulations in COMSOL Multiphysics and Simcenter STAR-CCM+ provide the basis for the selection of a suitable stratification device. The bearers in the room lead to the factor of three in the number of stratification devices so that the chambers in the upper part can all be accessed. The temperature level will be between 35 and 80 °C and three temperature layers are planned.

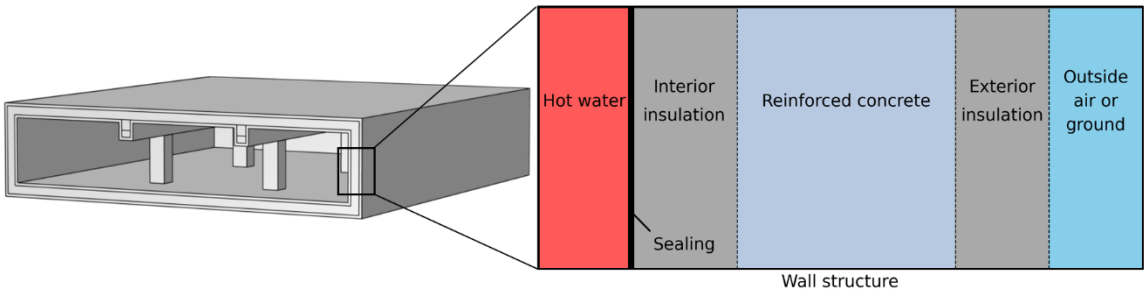

Fig. 1: Left: Sectional view of the 3D model of the cellar, right: Wall structure after transformation from concrete wall to heat storage [Source: iwe]

ORGANIC AND SILICON PHOTOVOLTAICS

Organic photovoltaics (OPV) as well as standard silicon photovoltaics will be installed on the area. A demonstrator of a bike garage with OPV has been successfully built to be able to load e-bikes self-sufficiently. This promotes the sustainable mobility of the employees of the companies located at Winterling area. Furthermore, OPV for a food stand and for street lamps produced by a commercial tenant of the area are under investigation. Silicon photovoltaics with 440 kW_p will be used for the large roof surfaces and a façade to reach a high share of green electricity. An additional battery storage could enlarge the autarchy of the area.

SMALL AND LARGE WIND TURBINES

A wind park with four turbines is located 3.5 kilometers north of the area. The first of these wind mills will loose funding of EEG in 2025. A power purchase agreement between the operator and the area or even the municipal utility could be a win-win for both parties. The operator can continue to sell his green electricity and the area as customer can enlarge the pool of renewables compared to only PV. Another possibility to use wind energy is to install a small wind turbine on the 50 meter high chimney which formerly was used for the kiln hall. A 10 kW horizontal wind turbine is investigated, especially static check-up is crucial for this special location.

LIFE CYCLE ASSESSMENT

A key objective of the project is to reuse as much of the existing building structure as possible. The buildings of the Winterling industrial complex were constructed over a period of approximately 100 years. The different building standards require an individual approach for modernization in order to comply with current energy efficiency regulations. This usually involves extra work compared to new buildings. However, the energy consumption for electricity, heating, ventilation and air conditioning is expected to be higher than for new buildings. To assess whether a new building is preferable to a refurbished one in terms of energy consumption, the modernised Winterling industrial complex is compared to a virtual new building of the same size. The criterion used is the CO_2 equivalent emissions over the life cycle of the building. This includes the energy required for construction, refurbishment, energy efficiency measures, waste disposal, recycling and the energy consumed during 50 years of operation. The results for the first building analysed show that renovation is the preferable option in terms of energy consumption.

LEGAL ASPECTS

The legal aspects mostly focus on questions concerning energy law. First of all, the best operating form for the Winterling area regarding grid connection and power supply have been examined. Questions concerning a common power supply, a common energy production and different consumption constellations have been analysed. Part of the project's legal aspects is also the installation of charging points for electric vehicles. An examination was conducted on how a battery storage system can be installed on the site to meet the requirements given by the different partners linked via the project concept.

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CONFERENCE TOPIC

This abstract refers to the following conference topics:

- Renewable heating and cooling
- Emerging heat and cold storage

- Sustainable Renovation
- Excess Heat Energy and Resource Recovery from Low-grade Sources
- Digitalization for Future Energy Systems
- Coupling of Energy Sectors
- Flexibility and Stability of Thermal and Electric Grids
- Life Cycle Assessment

EVALUATION OF THE ECONOMIC VIABILITY OF SOLAR GREEN ROOFS AS A BASIS FOR THE INTRODUCTION OF A SOLAR GREEN ROOF OBLIGATION

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SUMMARY

Solar green roofs are an effective measure to promote both climate mitigation and climate adaptation on the same roof surfaces in cities. Hamburg therefore wants to make the installation of green solar roofs on new buildings and when renovating the roofs of existing buildings mandatory in 2024. The basis of an obligation is the economic reasonableness for the obligated parties. Therefore, the ecological and social benefits of solar green roofs were determined in an expert report and the resulting economic advantages were estimated. This was used to calculate the amortisation periods for different sizes of solar green roofs. The article presents the calculation results and shows that in Hamburg solar green roofs on roof areas of 200 m² or larger are economically feasible.

Keywords: solar green roof, economic efficiency, obligation, climate adaptation

INTRODUCTION

The heat records in 2023 prove that climate change is progressing rapidly. In order to meet the UN climate goals of the Paris Agreement, the European Union is aiming for climate neutrality by 2050. This requires the replacement of fossil fuels with renewable energies. At the same time, however, in addition to climate protection, climate adaptation is also necessary in order to compensate for the effects of the temperature increase of at least 1.5 degrees Kelvin. Cities are at the centre of attention here, as an increasing proportion of the population lives in cities.

More and more cities are setting their own climate protection targets, such as achieving climate neutrality by 2030 (EU Cities Mission). An important component of this is the generation of solar energy on the roofs of buildings. Berlin, for example, wants to become a solar city and generate at least 25% of its electricity requirements on its own roofs. However, cities are also particularly affected by climate change, as heat builds up in public spaces above streets and between buildings and urban heat islands develop. At the same time, the sealing of soils means that the increasing number of heavy rainfall events can no longer be absorbed by the drainage systems. One countermeasure is green roofs, which can absorb rainwater (retention effect) and also cool the surrounding air through evaporation and help to improve the microclimate.

In Germany, there are several federal states, such as Baden-Württemberg, Berlin and Hamburg, which have introduced an obligation to install solar systems on new buildings and when completely renovating roofs on existing buildings. At the same time, there are a growing number of municipalities that are motivating their citizens to green their flat roofs, such as Berlin, Bremen and Hamburg. As both climate protection and climate change adaptation need to be strengthened, the insight is maturing that the use of flat roofs as green roofs or for solar power generation is not a competition, but can and should be combined in future. Hamburg is therefore currently preparing the obligation to install PV systems on extensively greened roofs (so-called solar green roof obligation) (Hamburger Senat (2023)). This article analyses the advantages of installing solar green roofs compared to PV roofs without green roofs and green roofs without PV systems in terms of economic and ecological factors.

CALCULATION OF ECONOMIC BENEFITS OF SOLAR GREEN ROOFS

This paper presents the results of a study carried out on behalf of the Hamburg Senate. The study compared the economic benefits of PV systems, green roofs and solar green roofs. The ecological and social benefits of green roofs were also described and their economic advantages (in business and economic terms) calculated.
The various green roof structures are described by way of introduction: Green roofs on flat roofs with an inclination of up to 10° and on pitched roofs with an inclination of 10 to 45° and the associated structures. Extensive and intensive green roofs, a biodiversity green roof, which specifically supports the preservation of biodiversity, and retention green roofs, which specifically increase the rain retention capacity, are also presented. The solar green roof is usually realised on extensively greened flat roofs with an inclination of up to 10°. The PV modules must allow sufficient light to pass between the rows of modules and enable green roof maintenance. The modules can be installed at different inclinations or, in the case of bifacial modules, also vertically.
In order to consider the economic viability, the period of time required to amortise the investment was determined. If the amortisation period is within the useful life of 20 years, the system is considered economically viable within the scope of the Hamburg solar green roof obligation.
The economic viability of a PV system depends on the investment and operating costs, the remuneration received for the solar electricity fed into the grid and the avoided electricity costs. Green roofs do not generate any income, but some savings can be claimed. The savings are listed in Table 1. Further results are presented in the paper.

Table 1: Overview of the benefits of green roofs and their calculated economic value (in the case of Hamburg)

Benefits of green roofs	**Economic value**	**Type of benefit**
Protection of the roof waterproofing layer by the green roof	Black roof: 25 years Green roof: 40 years	Extended service life
Retention: Reducing the costs of trough infiltration systems	39.50 €/m^2	One-off cost reduction
Retention: Reduction of the stormwater fee	0.38 €/m²/a	Annual cost reduction by 50 %
Thermal insulation of the building:	0.06 €/m²/a	Annual heating cost reduction
Cooling effect in the building	0.03 €/m²/a	Annual cooling cost reduction
Cooling effect on the PV modules	4 % additional solar yield	Increasing the solar power yield
Increase in real estate value	2.4 €/m /a^2	Possible increase in rental income
Air purification (PM_{10} , CO_2 , NO_2 , SO)$_2$	0.137 €/m /a^2	Social benefit
Cooling effects through evaporation: avoidance of heat islands	Not ascertainable	Social benefit
Biodiversity-promoting effect of green roofs	Not ascertainable	Social benefit
Noise reduction	Not ascertainable	Increased quality of living
Fire protection	Not ascertainable	Increased safety

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CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers: Policies

PV DRIVEN AIR HEAT PUMP USING OVERHEATING EFFECTS AS THERMAL BATTERY IN SINGLE FAMILY HOUSES

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SUMMARY

Theoretical investigations based on TRNSYS simulations are carried out for an electric driven air heat pump (AHP) in combination with different concepts for thermal activation of the building mass (TABS) and water storage (TES) in small single family buildings. TABS and TES are acting as thermal battery for local produced photovoltaic electricity. Several different heat pump characteristics and control strategies in combination with a single family house with different heat capacities (screed, concrete and water storage volumes) are investigated. Using PV with 7362 kWh gain per year the household grid electricity of 3058 kWh/a can be reduced by 35% to 1987 kWh/a. Air heat pump grid electricity of 3175 kWh/a as standard reference with PV can be reduced by 15% to 2676 kWh/a, but by 56% to 1251 kWh/a, when using building mass and water storage as thermal battery.

Keywords: heat pump, photovoltaic, thermal battery, single-family house, building mass activation

INTRODUCTION

Based on a set of theoretical simulations in combination with some field measurements in real buildings it was investigated how an air heat pump system in combination with different building types with different designed TABS can act as a thermal battery when supplying space heating and domestic hot water to the building with different control strategies.

The air heat pump can be operated in different ways like: a) power controlled depending on availability of photovoltaic electricity, b) with or without using a desuperheater for domestic hot water (DHW) preparation, c) charging a water storage tank at different temperature levels or d) heating the building to room temperatures with more or less hysteresis or space heating flow temperatures respectively.

Simulations are done for a single family house (based on the IEA SHC Task44 reference building) with low energy standard (RES45: 45 kWh/m2a) at central European climate of Innsbruck.

SIMULATION RESULTS

In Fig. 1 energies of the whole year are summed up for each hour resulting in one virtual “day” of the air heat pump system with a 40 m2 PV system. The left figure shows the reference system with standard control system. The right figure shows the heating system with both, overheating of the building mass and the water storage. A significant shift of the air heat pump operation to day time instead of operation during night time can be observed. This leads not only to much more air heat pump operation powered by the PV electricity, but also to operation during daytime periods with significant higher ambient air temperature resulting in higher COP.

Due to overheating of the building and the water storage of course, additional thermal losses exist. But the magnitude of 6% to 12% increased total heat pump electricity consumption leads to an efficiency of around 80% of the excess PV-electricity stored in the “thermal battery” instead of feeding into the grid. This in the same range as electric battery systems achieve typically.

Room temperatures due to overheating mainly increase as average values in the afternoon but not in peak temperatures due to the high damping effect of the floor heating system.

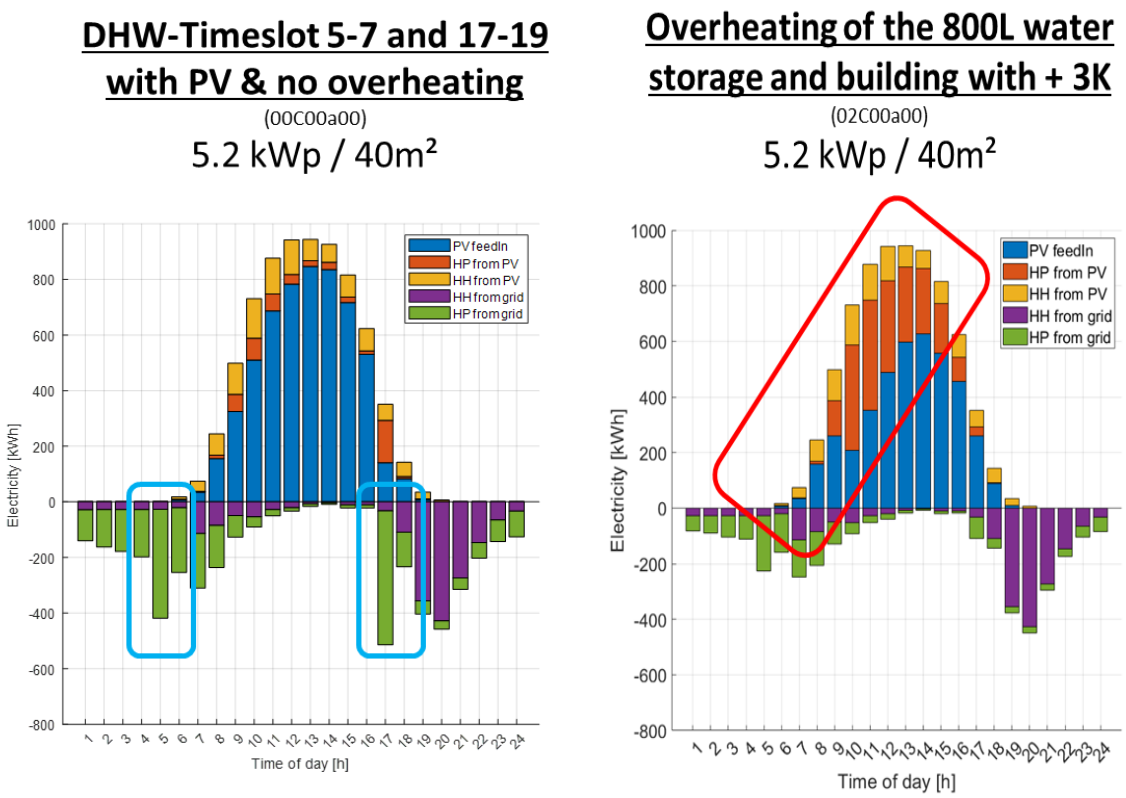

Fig. 1: Virtual 24-hour day of the whole year for the reference case with standard PV system (left) and with PV system with overheating the 800 liter water storage and overheating of the building with an extra lift of +3K of the flow space heating temperature (right).

CONCLUSIONS

For a PV - air heat pump system in a single-family house designed as a low energy building the grid electricity consumption can be halved compared to a PV – air heat pump system without overheating control concept. Several boundary conditions and parameters were studied concluding that a typical screed thickness (0.08 m) of a floor heating system with about +3K increased space heating flow temperature during PV-overheating already results in around 30% additional operating cost savings compared to a standard control concept.

The potential of storing heat in a standard floor heating system (screed thickness 0.08 m) is in the same range as of a 800 litre water storage: around 30 kWh. Due to several dynamic effects and operational boundary conditions, even a concrete core sealing of 0.2 m thickness used as thermal battery does not lead to significant different results.

PV self consumption just for heat pump operation can be quadruplicated. Including household electricity consumption for the entire system still the PV self consumption can be doubled. This is roughly the same effect as a chemical battery typically can achieve (with typical design of: 5 kWh capacity for a 5 kWp PV system), but much more cheaper since no investment cost occur for the “thermal battery”, which is anyway in the house.

Even though the room air set temperature during PV-overheating is increased from 21°C to 24°C, the finally resulting room air temperature as mean value in the winter period just increases by 0.3K. The peak temperatures during day shows almost no increase but the period from late afternoon to after midnight stays at about 0.5K to max 1K higher after a sunny day.

CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

“Renewable heating and cooling, including high temperature applications” or “Coupling of Energy Sectors”

ROLE OF SEASONAL THERMAL ENERGY STORAGE COUPLED WITH HEAT PUMPS IN ACHIEVING THE ENERGY AUTARKY OF DISTRICTS

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SUMMARY

The study's main objective is to assess how seasonal storage technologies affect the energy self-sufficiency of districts. The research employs an hourly MATLAB-based algorithm, accounting for district energy demand, energy from generation sources, and energy stored in seasonal thermal energy storage (TES). Load curves for the districts are based on Austrian building stock scenarios. A simplified system, powered by a large-scale heat pump (HP) and PV field electricity, is considered for energy generation, with the HP size tailored to meet demand. The sizing of the TES is a crucial aspect, considering both winter peak demand and surplus energy availability in summer. The study also incorporates geometry and envelope characteristics to account for storage efficiency in the yearly energy balance. Various scenarios are considered, evaluating the achievable degree of energy self-sufficiency and the building stock's quality.

Key-words: Thermal energy storage, Primary energy, Energy autarky, Renewables

INTRODUCTION

In an energy system with increasing share of renewables (RE), seasonal energy storage solutions will play an increasingly relevant role to ensure energy supply stability and enhance system redundancy. The building sector, especially in cold climates, faces unique challenges due to seasonal energy demand variations. Implementing seasonal storage solutions is crucial to boost self-consumption of locally generated energy, reduce the need to purchase energy during peak price periods, and minimize excessive generation capacity. Large-scale water-based thermal energy storage (TES) in district heating (DH) systems has proven to be a very efficient solution to bridge the gap between winter and summer renewable energy mismatch, thus increasing the share of RE (Tschopp *et al.*, 2020).

AIM

This work aims at providing a reference study to evaluate the impact of seasonal storage technologies in increasing the energy autarky of districts. Given the strong seasonal pattern of the building sector's load curve, the study aims to identify key factors relevant to planning of positive energy districts (PED), considering both the energy demand and generation side. In the context of the energy transition, a RE-based heat production system is considered: the RE deployment is directly related to the degree of autarky achieved in the system. On the demand side, the study explores the impact of energy efficiency measures to reduce the final energy demand of buildings. This is done by comparing two different annual load curves: one for a building stock with ambitious renovation rates and building qualities and one for a business-as-usual path. In order to cover the seasonal energy mismatch, a seasonal TES is included to increase the energy autarky: a water-based TES system is considered in the analysis as one of the most well-established and cost-effective seasonal energy storage technologies.

METHODS

The study is based on an hourly MATLAB-based algorithm, which considers the energy demand from the district and the energy directly available from the generation plant and the one stored into the seasonal TES. The load curves for the two studied districts are derived from energy scenarios defined for the Austrian building stock (Tosatto *et al.*, 2023). On the generation side, a simplified system based on a large-scale heat pump (HP) powered by the electricity produced by a PV field is considered. The HP is sized on the load demand; an electric back-up heater is additionally considered for the TES charging, in order to maximize the PV self-consumption. A simplified scheme is presented in Fig. 1.

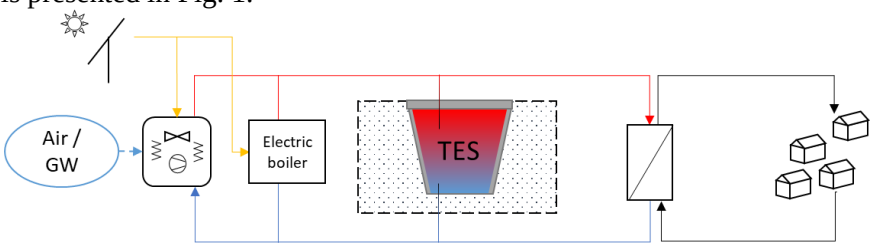

Fig. 1: Simplified energy flow of the studied system.

A fundamental part in this study is the sizing of the TES, which should consider both the peak energy demand of winter and the actual availability of summer surplus (peak power and excess energy). The storage is treated as a node, with correction factor (i.e. efficiency) to account for geometry and envelope characteristics available from literature (Ochs *et al.*, 2020) .

RESULTS

The key performance indicators used to compare the different cases are: the achieved degree of autarky, RE deployment (i.e. m^2 of PV), size of the TES. A summary of preliminary results is presented in Fig. 2.
The left figure shows the daily profiles of the DH grid and the HP production for different PV field sizes, both based on the Innsbruck weather data. The energy gap between demand and production is used to size the TES. The resulting yearly energy balance is presented in the right figure, which shows for the different investigated PV field sizes the share of energy covered by HP and TES discharge.

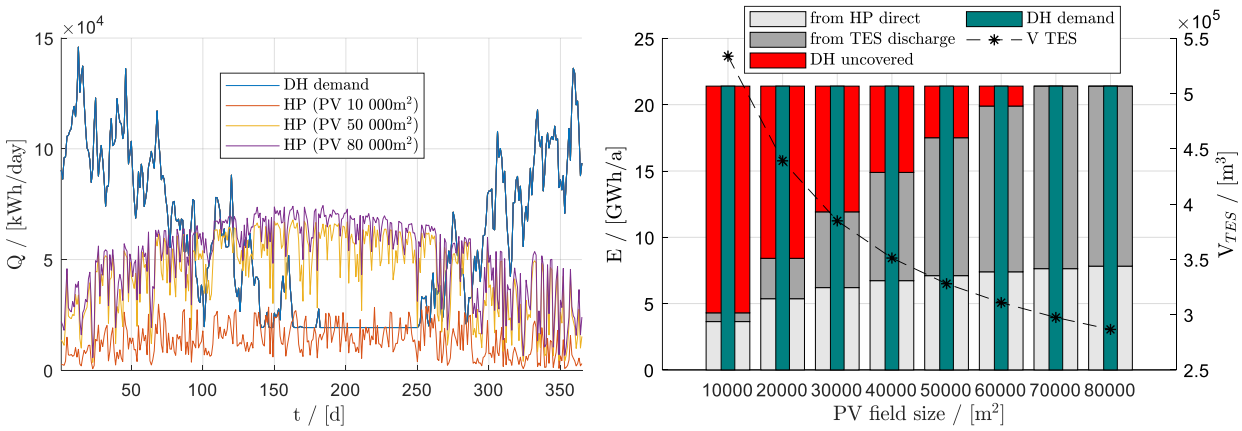

Fig. 2: (a) DH demand and generation profiles. (b) Yearly balance considering the presence of a seasonal TES.

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CONFERENCE TOPIC

Emerging heat and cold storage

THERMO-ECONOMIC ANALYSIS OF COLD-WATER DRAW-DOWN SYSTEM IN A NEWLY INSTALLED INDUSTRIAL SOLAR WATER HEATING SYSTEM AT A MILITARY BASE IN BOTSWANA

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INTRODUCTION

Ordinarily during the night and other times when showers are not in use, the hot water in the pipes cools down. When showering resumes, users are normally pressured to drain the cold water down until the pipes fill up with hot water from the hot water storage tank. This draining down is a waste that has been solved by introducing a drain-back circuit, which drains the cooled water back to the hot water tank and not down to the drain. It is a saving that comes with costs and risks that have not been evaluated clearly in the reviewed literature. This drain-back system is an extra circuit of pipes that connect the furthest end of the hot water supply line (after the last shower) back to the hot water storage tank. During moments of no activity, the hot water in the supply line cools down. At 30 ºC a drain-back circulation pump is triggered to drive water around the supply pipe until the supply line reaches 40ºC. In this whole process of saving water, electricity is used to drive the water around; the line is repeatedly refilled with hot water that later cools down, adding up to volumes that were earlier cooled; if this extraction of hot water to a cooling line results in significant loss of heat from the storage tank, it will lead to the electrical backup compensating the heat that was pumped out. This paper carries out a thermos-economic analysis to evaluate the worthiness of this fairly new practice of water saving, vis-à-vis the costs of doing so. State of the art energy meters, heat flux sensors, surface temperature loggers and thermographic camera were used to gather data from the system. In conclusion, it is not a given that the drain-back system brings savings. Preliminary findings suggest that there is high likelihood of approach increasing costs.
Keywords: Industrial solar water-heating, thermo-economics

MATERIAL AND METHODS

The system under investigation

RESULTS AND DISCUSSION

CONCLUSIONS & RECOMMENDATIONS

TECHNO-ECONOMIC ANALYSIS OF THE HEATING SYSTEM ROBUSTNESS

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SUMMARY

A multi-apartment building has been built in Innsbruck (Austria) and monitored for the first two years of operation. Monitoring data analysis show a particular higher space heating demand (36 kWh/(m^2 a)) than designed (11 kWh/(m^2 a)). The aim of the current study is to quantify the robustness of several heating systems, i.e. highest final energy savings and economic benefit, in different boundary conditions. Eight system combinations are considered, varying the heat generation (direct electric as-built, air/water heat pump and ground/water heat pump) and size of the photovoltaic system. The systems are tested in two building models: pre-design model and a model adapted to the monitored boundary conditions and monitored energy consumption. Concerning final energy optimization, the most robust system is an air-source heat pump with a 32 kWp photovoltaic system, while concerning economic optimization, an air-source heat pump is suggested without a photovoltaic system.

CASE STUDY AND MOTIVATION

The building considered in this study is a small multi-apartment building built in Innsbruck. The building accommodates people for a temporary assisted living environment i.e. specific user behaviour. The building was planned according to the Passive House standard with PHPP (Passive House Planning Package) to a space heating demand of 11 kWh/(m^2 a). The installed heating system is completely electric for space heating (SH) and domestic hot water (DHW). A large photovoltaic system of 32 kWp covers the south façade of the building and electric batteries (total capacity of 20 kWh) are installed in the basement. The concept is to keep the investment costs low, minimize the installation effort and neglect distribution losses, while increasing the share of on-site renewable energy production. Monitoring data of the first two years of the building is available. Monitoring data show a particular higher SH demand (36 kWh/(m^2 a)) than designed (11 kWh/(m^2 a)), while DHW demand and appliances demand are lower than the design. Electricity consumption for mechanical ventilation and photovoltaic energy production are similar to the design. A detailed comparison has been carried out and the influence of user behaviour has been investigated (Venturi et al., 2023).
Several monitoring studies confirm the effectiveness of the Passive House standard in practical application (Feist et al., 2007; Peper et al. 2015; Johnston et al., 2020). Nevertheless, there are also some cases where a mismatch between the predicted building performance and the real performance (monitoring data) was shown (Calì et al., 2016; Zou et al., 2018). The mismatch should be addressed to the different boundary conditions between design and reality such as user behaviour and climate. The aim of the current study is to identify the robustness of the system used, in terms of final energy savings and economic benefits varying the building boundary conditions. The most robust system therefore is the optimal system in a range of boundary conditions including design and unexpected “extreme” conditions.

METHODOLOGY

In the current study, eight system combinations of heat generation system and photovoltaic system are modelled. The considered heating systems are: direct electric (as-built), centralized air-source heat pump and centralized groundwater-source heat pump. The photovoltaic sizes range from 0 to 70.9 kWp (which is the PV capacity

achieved by covering also the East and West roofs with PV panels). The combinations are presented in Table 1. As reference system (REF), the combination of direct electric heating system and no photovoltaic system is chosen.

Table 5: Description of the investigated systems (SH, DHW and PV technologies)

Case	SH and DHW system description	PV system description
REF	Direct electric system	No PV system
A	Direct electric system	32.0 kWp – South façade
B	Direct electric system plus shower drain-water heat recovery	32.0 kWp – South façade
C	Direct electric system	70.9 kWp – South, East & West façade
D	Centralized air-source heat pump (4-pipe distribution system)	No PV system
E	Centralized groundwater-source heat pump (4-pipe distribution system)	No PV system
F	Centralized air-source heat pump (4-pipe distribution system)	11.8 kWp – South façade
G	Centralized air-source heat pump (4-pipe distribution system)	32.0 kWp – South façade

A techno-economic analysis is performed. The KPIs of the study are the final energy savings and the additional costs compared to the refence system. The final energy savings are calculated on monthly-basis with the PHPP. The economic analysis is carried out considering for each component of the system, the costs for investment, installation, maintenance and operation. The economic analysis is carried out with the method of the equivalent annual cost (EAC).

The systems are implemented in the original building model (as designed, called "Design Building" with a space heating demand of 11 kWh/(m^2 a)) and in an adapted building model (as monitored, called "Parametrized building" with a space heating demand of 36 kWh/(m^2 a)). The "Parametrized building" model is created assuming the monitored boundary conditions (climate, internal temperature, internal gains) and the monitored energy consumption (SH, DHW, appliances and ventilation).

PRELIMINARY RESULTS AND CONCLUSIONS

The most robust system differs concerning final energy or economic analysis. The highest final energy savings are obtained with system G (Table 1) i.e. an air source heat pump combined with a 32.0 kWp photovoltaic system on the south facade. The highest economic savings are achieved by system D (i.e. an air-source HP without a photovoltaic system, respectively). The preliminary economic savings with the "Parametrized building" are significantly bigger than with the "Design Building". As in the reality more energy is required than designed, a heat pump is more economic convenient than a direct electric system (reference case) thanks to its higher efficiency. A more robust system therefore allows bigger energy and economic saving in case the real consumption overcomes the design consumption.

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CONFERENCE TOPIC

Solutions for Energy Efficiency

INTEGRATION OF CHARCHING POINTS IN RENEWABLE ENERGY COMMUNITIES IN AUSTRIA

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SUMMARY

Renewable energy communities (REC´s) aim to achieve a high proportion of electricity self-consumption (ratio of self-consumption to self-generation) due to reduced grid charges for self-generated electricity. Electricity consumers with time flexibility, such as e-vehicles that adapt consumption to current generation, can increase the proportion of self-consumption and enable e-vehicle users to benefit from a price advantage for the purchased electricity. The focus group research, which was carried out as part of the NETSE project (User-oriented development of technologies and services for energy communities, Smart City Project), examines the potential and barriers to the integration of e-charging points in REC´s. Use cases were derived by experts and visualized and verbalized in the form of service blueprints. The service blueprints and verbal concepts were discussed in two focus groups and hypotheses were derived. One central hypothesis is that e-charging points operated by REC members can provide added value for REC members, especially for those without the possibility of generating their own electricity (multi-family dwellings) and increase the share of self-consumption of the entire REC.

Key Words: renewable energy community, charging, electric vehicles, barriers

INTRODUCTION

Since July 2021, the Renewable Energy Package (EAG) has made it possible to establish energy communities. The number of energy communities, especially renewable energy communities (RECs), is growing continuously. In November 2023, over 200 RECs were registered on the energieemeinschaften.gv.at platform. RECs aim to achieve the highest possible self-consumption rate of jointly generated electricity in order to generate electricity price advantages. One way to increase the self-consumption rate is to charge electric cars in times of surplus electricity in the community. This is usually the case around the middle of the day due to the high proportion of PV electricity. REC members who charge their electric vehicle with REC-electricity at lunchtime increase the self-consumption rate and charge electricity at a discount.

AIMS AND RESEARCH QUESTIONS

The central research questions were: Which stakeholder in an EEG could become active as the operator of an e-charging point? Who would use the offer and what are possible barriers to success?

METHODS

1. Brainstorming: Experts collect ideas for implementation paths and prioritize them.
2. Service Blueprinting: Service blueprints are created from the two top-ranked ideas and these are written down in verbal concepts in simple language.
3. Focus group research: The service blueprints and verbal concepts were reviewed and discussed in two focus groups. The focus group participants were recruited from an interested group of REC´s (n>600), whereby they had to fulfill two criteria: 1) membership in an energy community or interest in membership and 2) practical experience in handling an electric vehicle. The focus groups were held online via MS

Teams Conference on July 26 and 27, 2023 with five and three participants. A semi-structured interview guide, the verbal concepts and the service blueprints were used.

RESULTS

The following diagram shows the electricity and cash flows for the use case that a member of the REC operates a charging point. In another concept, the charging point is operated by the REC itself (association, cooperative).

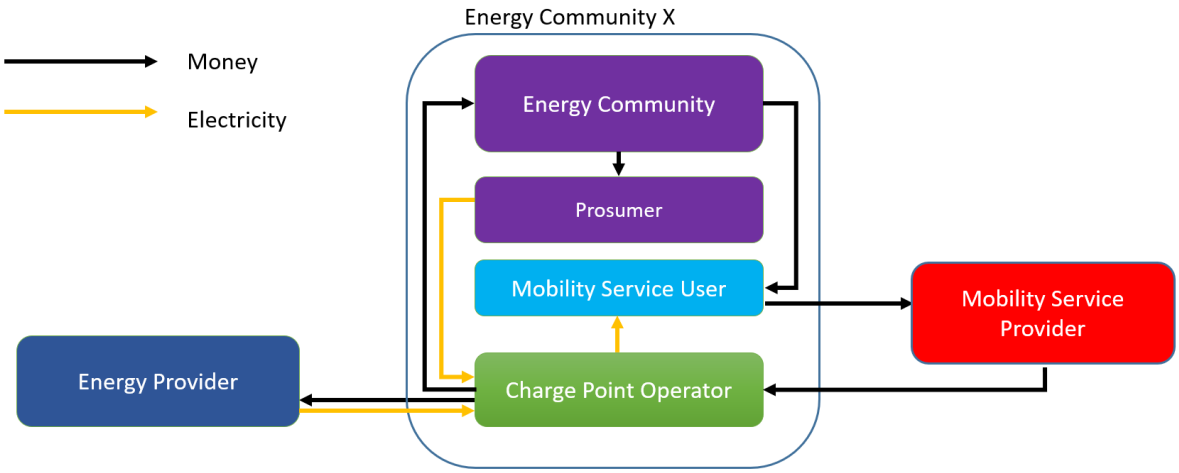

Fig. 1: Flow Chart: EC-Member as Charge Point Operator

The key findings are presented below in the form of five hypotheses as a result of the two focus groups:
H1: Charging REC-Electricity at a charging point operated by a REC member is only useful for people without the ability to generate electricity themselves.
H2: The operation of a charging point at which only REC members charge is not cost-covering as the investment and operating costs cannot be covered due to insufficient charging capacity and correspondingly low electricity sales.
H3: The charging REC member requires information on whether REC electricity is available at the desired charging time, otherwise the uncertainty as to how high and whether there is a price advantage at all is so great that the charging point is not used.
H4: The grid-related proximity between home and charging point (both must be in the REC) reduces the attractiveness of the charging point.
H5: Fast chargers are also more attractive in RECs than slow chargers, as the stay at the charging point must be as short as possible.

In the further course of the project, the hypotheses will be tested by means of a quantitative survey. The results are expected at the end of January 2024

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CONFERENCE TOPIC

Smart Services and System Operation (cross-cutting themes)

SUSTAINABILITY AND RESILIENCE NEXUS IN A LOCAL CONTEXT WITH LOW SELF-SUFFICIENCY

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SUMMARY

As the need for transitioning to sustainability grows, the security situation in Europe has worsened over the past year, underscoring the urgent need to ensure resilience in the energy system. The work presented here will address the connection of the perspectives of resilience and sustainability by designing a collaborative modelling approach for exploring the dynamic interplay between local industrial systems and low energy self-sufficient communities. The work is connected to an ongoing current development in the city of Malmö in Sweden.

INTRODUCTION

The literature on combining sustainability and resilience indicators into a unified assessment has identified three generalized types of frameworks for organizing sustainability and resilience: resilience as a component of sustainability, sustainability as a component of resilience, and resilience and sustainability as separate objectives. Marchese et al., 2018 found that implementations of these frameworks commonly aimed at providing benefits to people and the environment under normal and extreme operating conditions, but measures with high focus on either resilience or sustainability alone could potentially have a negative impact on the other, as seen in Figure 1.

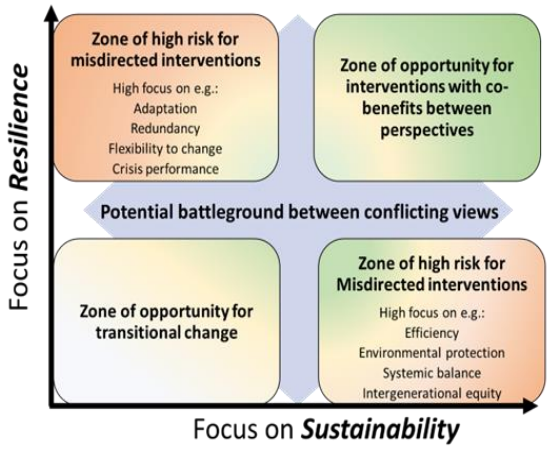

Fig. 1: Visualization of the importance of addressing both resilience and sustainability when developing long term strategies for industrial energy supply and demand.

A MEDIATING APPROACH; CO-DEVELOPMENT OF RESILIENCE AND SUSTAINABILITY

The main goal of the project presented here is to develop an integrated, collaborative, and explorative modelling approach to avoid the battleground between perspectives, as depicted in Figure 1, by moving the focus more towards the upper right corner of this figure. One central aspect will be the treatment of the specific system as a

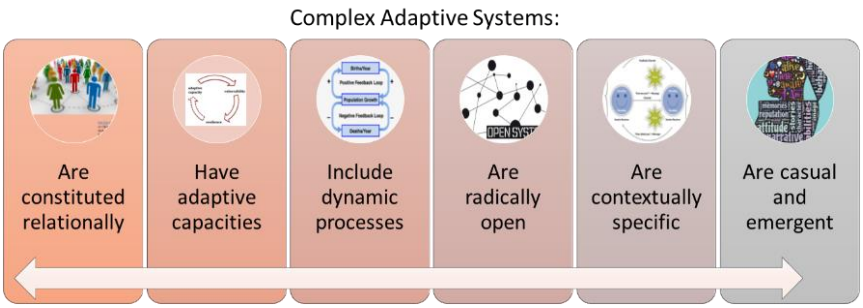

Fig. 2: Six organizing principles for Complex Adaptive Systems.

Complex Adaptive System (CAS) (Preiser et al., 2018). This typology implies six organizing principles depicted in Figure 2.

The case under study is an ongoing development between industries and the local society in the harbour of Malmö in Sweden. To capture the sociotechnical aspects of the complex adaptive system (harbour of Malmö), an integrated approach comprising of three layers of modelling is developed. One fundamental aspect of the structure, as depicted in Figure 3, is the integration of knowledge between the different modelling types. The three layers in Figure 3 are:

- The base of the pyramid in Figure 3 depicts the collection of data and development of models that describe the components of the technical system and its existing and future potential developments. This is for example thermodynamic simulations of processes, and energy system models describing the area of study.

- The second level of Figure 3 depicts the CAS-based, sociotechnical model that aims to capture and explore the interaction between the industries and the local society in the harbour of Malmö and will include aspects linked to the ability of industries to deal with potential disruptions. This model will be based on a System Dynamics approach and will be developed in group model building workshops together with the stakeholders in the system of study.

- The top level of Figure 3 depicts the development of models for interaction, exploration, and communication of the learnings from the modelling studies. Since there are a number of stakeholders and different roles in the system that will be involved in the modelling process, the communication of outcomes from this work will need to be tailored towards each respective receiver, e.g., engineers, management, decision-makers, community.

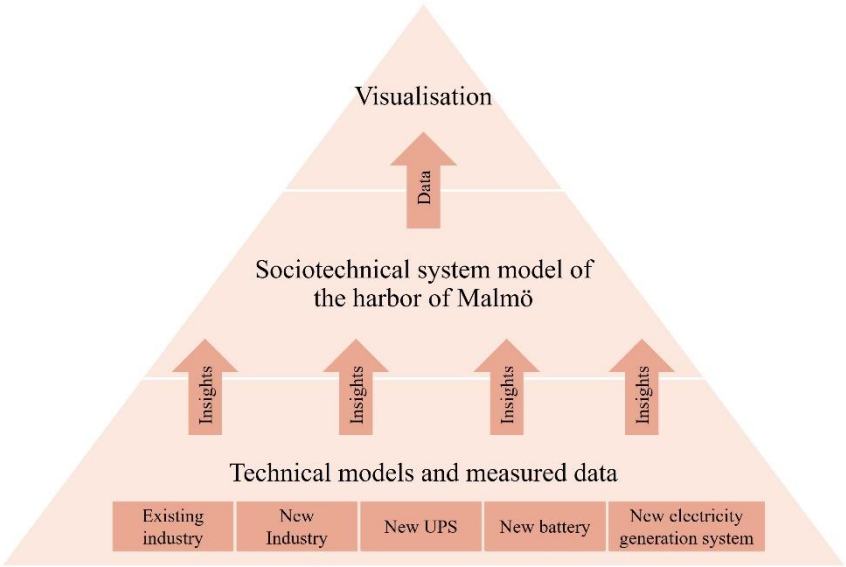

Fig. 3: Visual representation of a model structure intended to capture sociotechnical aspects of the complex adaptive system that is the harbour of Malmö.

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CONFERENCE TOPIC

Coupling of Energy Sectors

SOLAR ENERGY ALTERNATIVES FOR COAL BOILER STEAM PRODUCTION

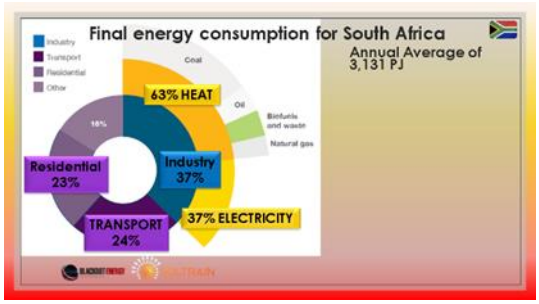
Wally Weber
BLACKDOT Energy
South Africa

SUMMARY

The South African energy volatility in both supply and pricing, opens opportunities for alternative Renewable and sustainable energy technologies in the market. Currently the focus is primarily on electricity generation, however more than 60% of the final energy consumption in Industry is heat and thermal energy.
A decade of Austrian support and investment through the SOLTRAIN program, has paved the way for a new era of solar thermal heating technology uptake in the Southern African industry and economy.
BLACKDOT Energy Engineering is a South African company that benefitted from the Austrian relationship. BLACKDOT completed the design and implementation of the first Southern African Solar District Heating system with the guidance and support of the Austrian SOLTRAIN Program. The Austrian investment in South Africa has ensured that South Africa is ready for the roll out of commercial large scale solar thermal systems and district heating programs.
Thermal heat energy transition, is a key component to achieve Zero Emission manufacturing objectives.
Keywords: Solar Thermal, South Africa, District Heating, Process Heating, SOLTRAIN

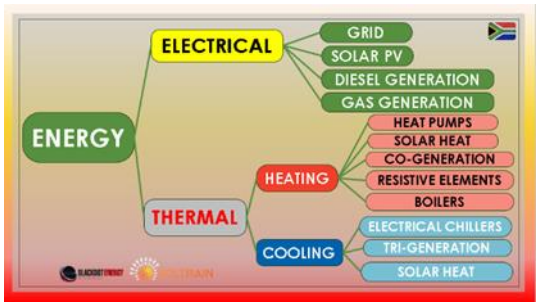
STEAM BOILER PROCESS HEAT PRODUCTION FROM COAL

Industry energy requirement analysis



The South African final energy consumption averages 3131 PJ per annum. Of this total energy consumption, 37% of that energy is consumed by energy for the industrial sector. Of the industrial energy, 63% of that energy is required for process heat.

The technology options for industrial heat consists of heat pumps, solar heating, co-generation, resistive elements, and fuel boilers.



The South African industry is primarily a coal-based energy generation driven infrastructure. It has also been the preferred technology for process heat and steam applications. The Primary technology for steam production in the South African commercial industry is the John Thompson-type Coal boiler system. due to the cost competitiveness of coal, alternatives to steam production (from a financial perspective) could be a challenging scenario if considered on a financial basis only.

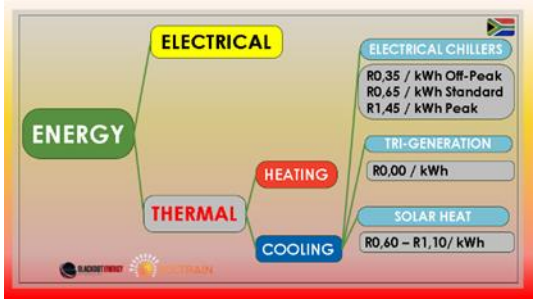
The cost of electricity

Considering the cost of electrical energy, the current generation alternatives are:

- Grid energy averaging from R1.40 / kWh in off-peak, up to R5.80 / kWh during peak.
- The alternative is solar PV power generation, averaging from R0.90 / kWh to R1.10 / kWh
- Most of the industry in response to load shedding, have installed diesel generation capacity, of which the costs averaged between R6.50 to R8.50 / kWh depending on the ever-increasing diesel price.
- Gas generation using natural gas can deliver power generation between R2.20 to R3.50 / kWh. The constraint is that load acceptance is not preferred for gas generation, which could be easily achieved with diesel generation with high torque capacity.

The cost of Cooling

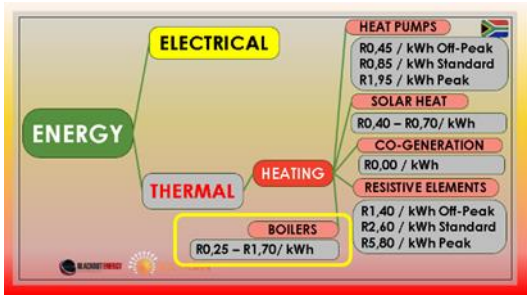
Considering the cost of cooling energy, the current generation alternatives are:



- Conventional electrical chillers, can produce cooling at an average cost of R0.35 / kWh off-peak, up to R1.45 / kWh during peak. The main advantage of electrical chillers is the fact that these units operate at a COP of 4.
- When considering the benefits of trigeneration, the cost-recovery and has already been achieved with the electrical power generation. The related available thermal energy which has been processed through an absorption chiller into cooling, results in the cooling energy (although only at a COP of 0.7) is from a financial perspective produced at a cost of R0.00 / kWh.
- Solar cooling utilizing solar heat, processed by an Absorption Chiller (at a COP of 0.7), can deliver cooling at competitive rates between R0.60 to R2.10 / kWh. The technology hurdle regarding solar cooling, is that from a commercial perspective the energy density and amount of cooling required, versus available roof space does provide a challenge in generating enough solar heat subsequently converted to cooling, for what the processes actually require in volume.

The cost of Heating

Considering the cost of heating energy, the current generation alternatives are:



- Considering the capacity of heat pumps the cost of thermal energy can average from R0.45 / kWh Off-peak up to R1.95 per / kWh during peak.
- Solar heating has numerous projects in SA, providing heating energy averaging from R0.40 to R0.70 / kWh.
- Co-generation utilizing waste heat from an electrical power production, can provide heating from a financial perspective at R0.00 / kWh.
- Resistive elements that are still utilized in electrical boilers, can deliver thermal heating at a cost of R1.40 / kWh off-peak, up to R5.80 / kWh during peak.
- Fuel boilers can deliver heating energy on average between R0.25 / kWh, up to R1.70 / kWh depending on what fuel source is used, from coal, or oil, or paraffin-based fuel sources.

Renewable energy and heating as a viable alternative

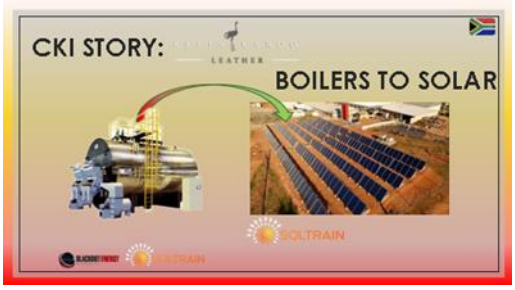
In all three aspects of industrial energy including electrical, cooling, and heating, it is clear that renewable energy can provide financially competitive alternatives. A number of feasibility studies were conducted on large industry energy consumers during 2019 to 2023.

In all these feasibility studies it became clear get the energy density of the industrial uses within the physical space of the facility, results in a limitation of viable implementation of renewable Solutions specifically industrial heat.

The energy requirement in physical space, compared to what could be delivered from the roof area, is the limiting factor to the successful implementation of renewable heating for industry.

However, if carbon mitigation, maintenance cost, and long-term sustainability is considered, alternative such as solar heating does provide a financially competitive technology alternative.

SOLAR PRE-HEATING CKI STEAM PRODUCTION



One of the first pilot projects to illustrate the technical and financial feasibility of a hybrid solar pre-heating for steam boilers was done at CKI which is a Tannery process requiring significant amount of process heat.

This project was a reduction of energy cost, where oil is used for steam production. The oil cost made the project more attractive with solar heating combined with the SOLTRAIN funding contribution for demonstration projects.

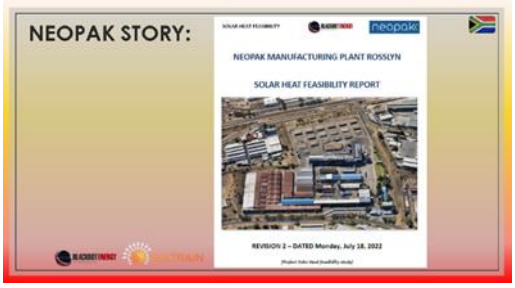
This project was an initiative to illustrate the technical viability of solar heating for boiler top-up water.

SOLAR HEATING FEASIBILITY STUDY FOR BMW SOUTH AFRICA

This study was done in two phases. The first phase was a conversion of the natural gas boilers to an alternative co-generation power, CHP program, as a carbon reduction initiative combined with high efficiencies.

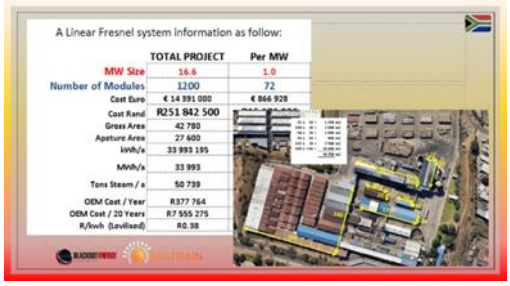
The second phase was an alternative approach to zero carbon production using solar linear Fresnel technology. This project proved to be financially and technically competitive, compared to the Natural gas boilers, and is currently in review for possible implementation.

SOLAR HEATING FEASIBILITY STUDY FOR NEOPAK SOUTH AFRICA



In this study there was technical and feasibility assessment done on a hybrid technology of coal and natural gas John Thompson boilers for steam production in a Paper Mill. This was initiated from a concern of industry regarding price hikes in natural gas given the conditions of the war in Ukraine and subsequent industry concerns of the cost of natural gas in South Africa.

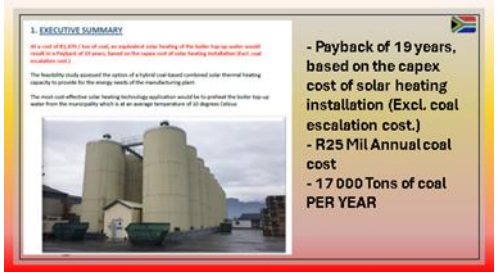
In this study, the option of both Solar Flat Plate Panel pre-heating of the boiler top-up water, combined with linear Fresnel Direct steel production was assessed. The limitations to the implementation of the Solar were twofold, firstly the limited availability of roof space and secondly the capex cost of the Solar plant implementation.



SOLAR FEASIBILITY STUDY DONE FOR CERES IN SOUTH AFRICA

In this feasibility study, the alternative of solar heating on a purely coal-based high-pressure steam boiler production was assessed. The financial viability was complex due to the competitive cost of coal, resulting in a payback period in the region of 19 years.

The reality of mitigating the carbon implications of coal-based process heat is that comparative financial alternatives are not feasible at this point in time, however, solar preheating does provide a technologically feasible solution that can be an on-Par cost competitive alternative to Coal based heating. In the scenarios of replacing existing boilers, the Capex decision and process will have to be strategically driven and not financially.



CONCLUSION

The feasibility studies compiled by BLACKDOT Energy conclude that solar heating provides a technically viable alternative to Coal-based steam production.

The conclusion is that the financial viability and competitiveness of solar heating are on a cost comparative benchmark. However, the capex implementation and financial viability, do pose certain challenges in implementation.

The transition towards a hybrid solar preheating and Direct solar steam production would have to be a phased approach driven by a combination of carbon strategy as well as possible incentive programs for the uptake of an alternative technology to a well-established coal-based solution.

REFERENCES

Green, C., (2020), Heating Systems for Houses, A Design Handbook. James & James (Science Publishers) Ltd., London, UK.

CONFERENCE TOPIC

Solar Energy Alternatives for Coal Boiler Steam Production

HEAT RECOVERY FROM A DECENTRALIZED SOURCE-SEPARATED WASTEWATER TREATMENT PLANT: A MODEL-BASED STUDY

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Email: shuoguang.yang@wetsus.nl

SUMMARY

Wastewater was classified as a renewable energy source in the revised Renewable Energy Directive of 2018. The separated collection of greywater would represent an opportunity for efficient heat recovery from household wastewater. This work presents the potential of applying a CO_2 heat pump to extract the energy from treated greywater within a decentralized source-separated wastewater treatment plant in the Netherlands. The study explores various heat recovery settings and compares their energy efficiency, carbon dioxide emissions, and greywater reuse potential. The findings indicate that this system effectively meets the district's showering-related energy demands, resulting in an 18.3% reduction in total domestic hot water energy consumption.
Keywords: Heat recovery, greywater, source-separated sanitation, CO_2 heat pump

INTRODUCTION

Wastewater contains a large amount of unutilized thermal energy (Cipolla & Maglionico, 2014), which can be recovered by heat exchangers and heat pumps (Nagpal et al., 2021). Greywater, consisting of discharges from showering, sinks, and laundry, possesses a higher temperature than mixed combined wastewater (Hernández Leal et al., 2010). A comprehensive exploration of heat recovery from a source-separated wastewater treatment plant (WWTP) that treats greywater and blackwater separately remains notably absent. This research introduces a greywater heat recovery system (Fig. 1) within a decentralized source-separated WWTP, treating wastewater from 250 households. This system employs a CO_2 heat pump due to its eco-friendly attributes and high performance in hot water production (Nekså, 2002). This work also evaluates the energy efficiency, carbon footprint, and greywater reuse potential across various heat recovery configurations.

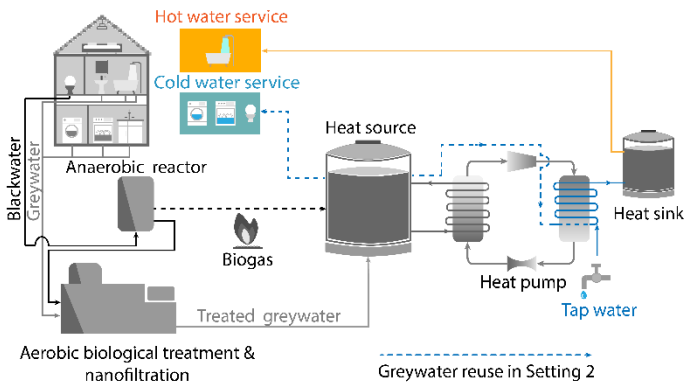

Fig. 1: Graphical representation of the greywater heat recovery system

MATERIALS AND METHODS

The greywater heat recovery system designed in this work is based on a pilot-scale, source-separated decentralized WWTP located in Sneek, Netherlands. Four different heat recovery settings (Table 1) are hypothesized to explore the system's efficiency and sustainability potential. In settings S1, S2, and S3, the aim is to recover heat from greywater for showering. In S2, this is coupled with greywater reutilization. In S3, the heating of water to 60 ºC is applied as this is the temperature required to meet the Dutch regulation to avoid the growth of *Legionella pneumofila*. On the basis of the four proposed settings, by developing a thermodynamic

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Austria

model using "Lee-Kesler Equation of State" for the calculation of the CO_2 refrigerant cycle, this study evaluates the performance of the CO_2 heat pump throughout a year in terms of the Coefficient of Performance (COP) and the carbon footprint of each setting. Moreover, this work explores the potential of water reuse, expressed as the percentage of treated greywater reintroduced into households.

Table 1: Definition of the four settings compared in this study

Setting	Elements included
S0	Source-separated WWTP (current status) without heat recovery
S1	Source-separated WWTP + heat recovery for shower (40 ºC hot water)
S2	Source-separated WWTP + heat recovery for shower (40 ºC hot water) + greywater reuse
S3	Source-separated WWTP + heat recovery for shower (60 ºC hot water)

RESULTS AND DISCUSSION

The CO_2 heat pump applied in the greywater heat recovery system showed high energy efficiency (Fig. 2). Specifically, in S1, the annual average COP of the heat pump achieved 6.7. By introducing greywater reuse year-round in S2, the COP drops to an average of 3.4. This decline is attributed to the increased pressure ratio of the heat pump compressor, which is necessary for re-heating a portion of treated greywater for showering after heat extraction. Compared to S1, S3 offers a relatively lower COP, with an average of 5.5, due to the higher temperature applied to avoid *L. pneumofila* growth. In S1, S2, and S3, as we assume that the greywater heat recovery system substitutes the utilization of natural gas to supply hot water for showering, there is a substantial reduction in CO_2 emissions. Compared to the current scenario (S0), the best reduction was achieved in S1, where the heat pump was estimated to emit 75.6% less CO_2 while providing the same quantity of heated shower water for 250 households.

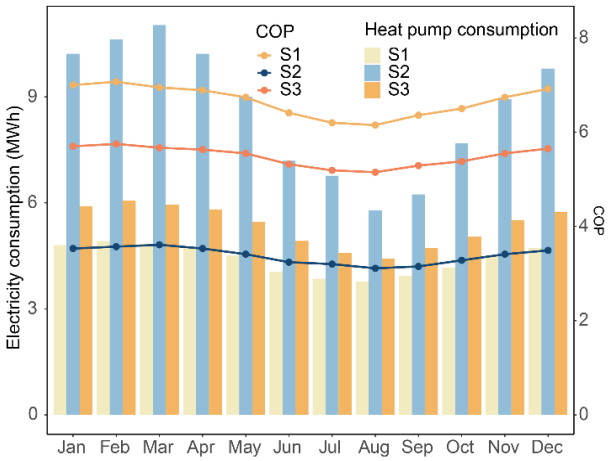

Fig. 2: Annual CO_2 heat pump performance based on model simulation in each of the proposed settings (S0, S1, S2, S3)

CONCLUSION

- The greywater heat recovery system within a source-separated WWTP can save 18.3% of the domestic hot water energy demand.
- In the design of a greywater heat recovery system, introducing treated greywater reuse for showering may decrease the overall energy efficiency.
- CO_2 heat pumps can deliver high performance in generating high-temperature hot water (60 ºC) using greywater as a low-grade energy source.

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CONFERENCE TOPIC

Excess Heat Energy and Resource Recovery from Low-grade Sources

STAKEHOLDER RECOMMENDATIONS AND RESEARCH FOCUS AREAS OF THE DISTRICT HEATING ALLIANCE AUSTRIA

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SUMMARY

In summary, our research and recommendations offer a holistic perspective on the biomass district heating sector. We firmly believe that collaboration across all levels of the industry, from technical innovation to policy advocacy, is paramount in advancing sustainable energy solutions. The biomass district heating sector has the potential to usher in a more efficient, environmentally friendly, and economically viable future, and our research endeavors stand as a guiding light on this transformative journey.

INTRODUCTION

We are delighted to present a comprehensive summary of our research services and recommendations tailored for stakeholders in the biomass district heating sector. Our insights stem from extensive discussions and hands-on experiences within the Austrian biomass industry, encompassing both technical intricacies and socio-economic considerations. These findings are pivotal in shaping the trajectory of sustainable energy solutions.

CONTENTS:

Our research predominantly revolves around two pivotal domains:
1) Recommendations for Stakeholders:
We gathered information from key actors, operators and owners of district heating plants throughout the entire project and summarized the results from hundreds of hours discussions in order to identify the needs of the sector. Finally, through our World Café session at the Biomass Conference 2023, we gleaned invaluable insights into the multifaceted challenges and opportunities that define the biomass district heating landscape. Here is a succinct distillation of the key takeaways:

Technical Recommendations:

- Fostering knowledge and competence through comprehensive training programs for facility operators.
- Emphasizing meticulous planning as it serves as the bedrock for operational success, including a focus on detail-oriented considerations such as emissions management.
- Advocating for increased automation while maintaining a focus on demand-driven operation.
- Crafting innovative solutions to accommodate load management.
- Pioneering optimization strategies for heat transfer station.
- Recognizing the paramount significance of blackout preparedness both from the supplier and customer ends.
- Promoting awareness of the dichotomy between district heating and non-district heating areas.
- Implementing robust leak warning system.

Political-Economic Framework Conditions:

- Navigating the challenges posed by the ever-evolving political landscape, particularly concerning regulatory frameworks such as RED (Renewable Energy Directive) III.
- Stressing the imperativeness of planning certainty to mitigate uncertainties inherent to the biomass district heating industry.
- Championing cross-border collaborations with EU member states to harmonize efforts.
- Spearheading public awareness campaigns and advocacy initiatives to elevate the perception of biomass utilization.
- Fostering regional cooperation and innovative procurement strategies to ensure and increase sustainable biomass sourcing.

2) Research Services:

Our research services are meticulously tailored to offer tangible support to the biomass district heating sector. Our comprehensive approach consists of three integral modules:

Module I: Initial Analysis with Data Collection

- Rigorous data collection to establish a foundational understanding of the district heating network.
- In-depth examination of operational data.
- Hydraulics-based calculations to optimize the district heating network.
- Assessment of generation facilities, with a focus on boiler efficiency.
- Exploration of opportunities for demand-driven heating.
- Recommendations for leak warning system installation.
- Capacity building through training programs and workshops for operators and stakeholders.

Module II: In-Depth Consultations and On-Site Visits

- On-site visits for hands-on assessments.
- Engagement in data-driven discussions to strategize for optimization.
- Collaborative efforts to identify areas of improvement.
- Support for the integration of new energy sources such as solar and geothermal.
- Detailed analysis and recommendations for system upgrades.
- Feasibility studies for network expansion.

Module III: Customized Action Planning and Implementation

- Detailed cost estimation and procurement assistance.
- Solicitation of competitive bids from service providers.
- Impact assessment of proposed upgrades on system efficiency.
- Monitoring and evaluation of implemented measures.
- Ongoing support for system optimization.
- Data-driven decision-making support.

Additionally, we offer:

- Evaluation of existing operational data to enhance performance.
- Optimization of generation facilities for improved efficiency.
- Training sessions and workshops to empower operators and stakeholders.
- Assistance with regional energy planning to optimize district heating infrastructure.

RESULTS:

Our research endeavors culminated in a rich tapestry of insights into the technical complexities, socio-economic considerations, and a suite of research services available to the biomass district heating sector. These insights provide actionable strategies to navigate current challenges and anticipate future trends.

Recommendations for Decision-Makers:

Our recommendations are directed toward key stakeholders in the biomass district heating sector:

- Technical professionals should prioritize comprehensive training and education, meticulous planning, and the gradual integration of automation technologies to enhance operational efficiency and sustainability.
- Policymakers must focus on ensuring planning certainty and creating an environment conducive to regional cooperation and cross-border collaboration.
- Advocacy groups should actively engage at the EU level, emphasizing the innovative potential of biomass utilization and its pivotal role in advancing renewable energy goals.

CONFERENCE TOPIC

Please indicate here to which of the Conference Topics this abstract refers:

- Renewable Heating and Cooling including high temperature applications
- Solutions for Energy Efficiency
- Digitalization for Future Energy Systems
- Flexibility and Stability of Thermal and Electric Grids
- Replacement of big fossil Power Plants by Renewables – Impact on District Heating

SOLCUBEGRAZ – LIVINGLAB INCLUDING RENEWABLE HEATING AND COOLING IN AN URBAN ENVIRONMENT WITH HIGH SOLAR ENERGY UTILIZATION

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SUMMARY

The SolCubeGraz project is not a classical scientific research and development project. It is rather an attempt to integrate the latest scientific results into the design and construction of a residential building in the city of Graz. The project will serve as a living lab and demonstration building for renewable energy utilization to a very high degree. After three years of planning, the project is now in the execution phase and will provide its first operational data in 2024. In the presentation, the results of the conceptual and basic design phases will be presented, including the results of different simulation approaches.

Keywords: autonomous building, building integrated photovoltaics (BIPV), solar-activated facade (SAF), thermal building activation (TAB), solar-assisted heat pump (SAHP).

INTRODUCTION

SolCubeGraz is a mainly privately financed project to demonstrate the best available technologies for renewable heating and cooling for a residential building in an urban environment (City of Graz). The main target is the utilization of locally available resources in the best possible way to reach a high degree of autonomy. Zero CO2 emissions and net zero OPEX are also relevant targets of this initiative. This project serves as a demonstration system for interconnecting emerging green technologies in the building sector. Providing data out of the field to further develop these technologies, including new control strategies for the interconnection, is also key.

MATERIALS AND METHODS

Desk research was the starting point for SolCubeGraz to evaluate all relevant publications within the scope of the project and to support the conceptual design phase. Covered topics are Building Integrated Photovoltaics (BIPV), Solar Activated Façade (SAF), Thermal Building Activation (TAB), Groundwater Cooling (GWC), and Solar Assisted Heat Pump (SAHP).

For the size of the identified and relevant system components, a model using IDA ICE has been created and validated. The dynamic building model also shows thermal comfort during all seasons, including the natural ventilation option within comfortable ambient temperatures. Hourly results of the total building energy demand will be used for detailed energy balances, including short- and long-term energy storage systems. Different

variations of the concept were tested, e.g., optimal design and orientation of rooftop photovoltaics or glare simulation of the vertically oriented PV modules on the façade.

RESULTS AND DISCUSSION

The result of the concept design phase is a system able to utilize locally available resources in the best possible way with high flexibility to cover all relevant demands by using different storage systems for energy and other resources.

Building integrated photovoltaic/thermal systems, including heat pump (BIPV/T-HP) will be the main energy source to generate heat/cold and electricity. The PV rooftop garden and the naturally ventilated façade in directions east, south, and west will produce electricity and heat/cold. Solar radiation will not only be utilized to generate electricity and heat but also for cooling applications. Radiative cooling is a good opportunity to establish cooling power without stressing local environments like air or water, especially in urban environments.

Collected renewable electricity will be directly distributed via a local DC nanogrid to loads like battery storage, an electric vehicle charger, and a heat pump. The DC nanogrid is connected to the public grid via a high-power bi-directional inverter. For seasonal energy storage and to increase self-consumption, the system is prepared for seasonal storage based on green hydrogen.

The main heating system is a solar-assisted groundwater heat pump for space heating and domestic hot water. The cooling is a direct cooling via groundwater and concrete core activation of all ceilings. Two stratified tanks, one for heat and one for cold, will be used for short-term thermal energy storage. The storage tanks will be managed using an exergy/anergy approach.

In addition to power and low-temperature heat generation via fuel cells, stored green hydrogen will be used for high-temperature applications. This includes a hydrogen-gas-fired sauna heater and an outdoor hydrogen-gas-fired cooking stove or barbeque.

CONCLUSION

After more than 3 years of intensive desk research, simulations, and the conceptional and basic design phases, the SolCubeGraz project is now in execution. The first operational data will be available in 2024. Further developments will be the optimization of the interaction of different system components and the set-up of a resource-oriented control strategy. The data generated from this project will serve as the basis for further developments in renewable heating and cooling in urban environments.

ACKNOWLEDGMENTS

This project has been funded by support from the Provincial Government of Styria. The conceptual and basic design phases have been supported by Kaltenegger & Partner Architekten, Kurt Pock ZT Tragwerksplanung, Sautter ZT – advanced energy consulting, Ogrisek und Knopper Elektrotechnik.

CONFERENCE TOPIC

This abstract refers to the topic “Renewable heating and cooling, including high temperature applications” for buildings.

Fig. 1: Rendering of the SolCubeGraz building

Fig. 2: Rendering of PV rooftop garden

Fig. 3: SolCubeGraz in the Execution phase

Fig. 4: Concrete core activation in SolCubeGraz

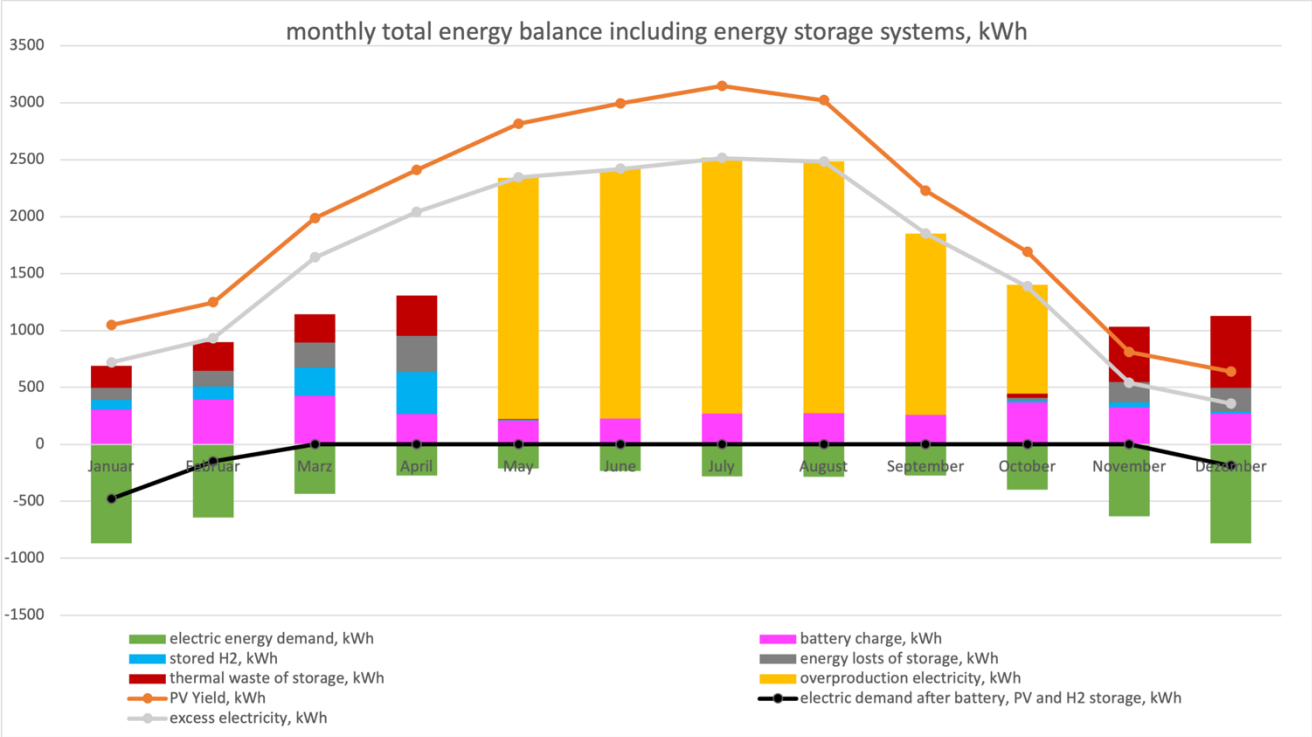


Fig. 5: Monthly total energy balance, including energy storage systems

CLIMATE ACTION PLAN FOR COMPANIES

The climate action plan for companies, the new guideline of klimaaktiv – the climate protection initiative in Austria - outlines the key elements of a plan to achieve the climate targets in the energy sector.

On the one hand, this guide is aimed at energy consultants who support companies in identifying measures. On the other hand, it is an aid for companies that are involved in the strategic planning of energy-related measures to achieve climate neutrality.

Developing a climate action plan

The climate action plan shows the measures planned by the company up to 2030 and beyond to continuously increase energy efficiency, reduce energy consumption and gradually phase out fossil fuels. Part of the climate action plan is a monitoring tool that is made available to interested companies and consulting firms. klimaaktiv partner companies are accompanied and supported on their path towards climate neutrality in annual target achievement meetings. The experiences and milestones of the companies are presented to the klimaaktiv network in events such as webinars, workshops, conferences and podcasts.

Further information:
www.klimaaktiv.at/energiesparen/energieeffiziente_betriebe/klimaaktionsplan.html

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

klimaaktiv

ENERGIE STEIERMARK

Energie Steiermark
Official Partner of a Green World

KEY FACTS

ENERGIE
STEIERMARK

As one of the **largest service providers in Austria**, Energie Steiermark focuses on **energy efficiency** and **innovative services** in the fields of electricity, natural gas, heat and mobility.
Over **2,000 employees** bring their experience and skills into a **fair partnership** with around **600,000 customers** at home and abroad.
In terms of generation, Energie Steiermark AG focuses exclusively on **renewable energy** from **water**, **wind**, **sun** and **biomass**.
The state of Styria is the majority shareholder.

KEY FACTS

ENERGIE
STEIERMARK

100 Years of Tradition:
State Coat of Arms as a **Distinction**

Fourth-largest Energy Company in Austria

2.000
Employees

600,000
Customers at Home and Abroad

Turnover of 1,616.5 Million Euros
103,2 Million Euros Operating Profits (EBIT)
Equity Capital Ratio of **48.9 %**

Electricity, Natural Gas, Community Heat
and Energy Services

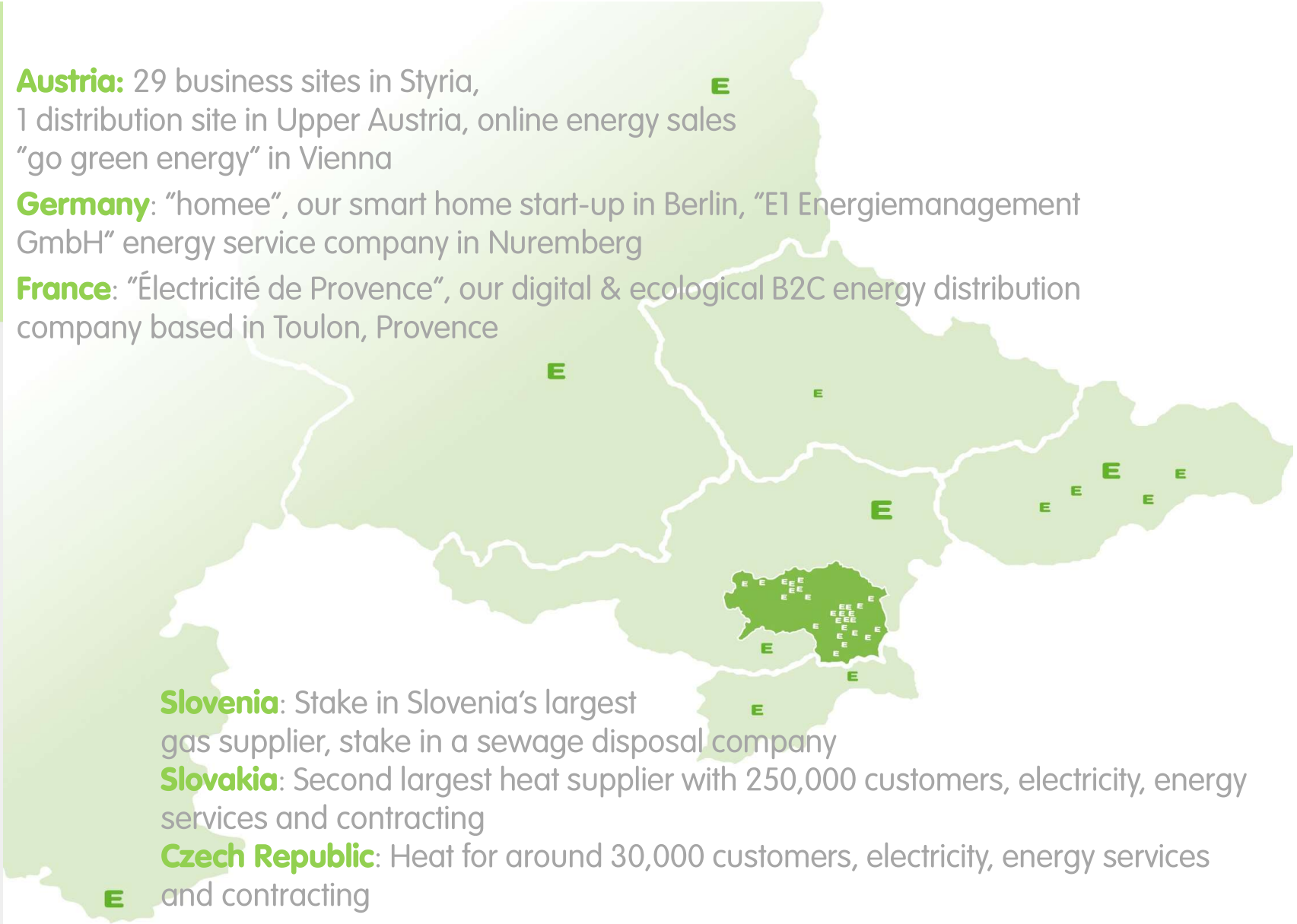
KEY FACTS

ENERGIE
STEIERMARK

Austria: 29 business sites in Styria,
1 distribution site in Upper Austria, online energy sales
"go green energy" in Vienna

Germany: "homee", our smart home start-up in Berlin, "E1 Energiemanagement GmbH" energy service company in Nuremberg

France: "Électricité de Provence", our digital & ecological B2C energy distribution company based in Toulon, Provence



Slovenia: Stake in Slovenia's largest gas supplier, stake in a sewage disposal company

Slovakia: Second largest heat supplier with 250,000 customers, electricity, energy services and contracting

Czech Republic: Heat for around 30,000 customers, electricity, energy services and contracting

KEY FACTS

ENERGIE
STEIERMARK

Rating "A stable"
Standard & Poor's

CUSTOMER EXCELLENCE
QUALITY AWARD 2022
MARKETINSTITUT

BRANCHEN SIEGER
ENERGIE STEIERMARK
2022
Stromanbieter
ZIELGRUPPE: KUNDEN/KONSUMENTEN
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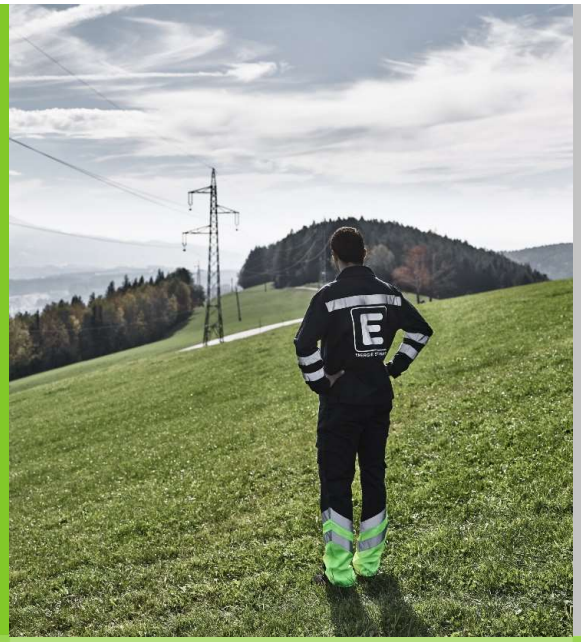
#1 trend Austria's 300 Best Employers 2023
(sector ranking: raw materials, energy, supply and disposal)



gogreenenergy

GAS SUPPLIER test winner
ÖGVS & trend / Gas Supplier Test 21

ÖGVS | Gesellschaft für Verbraucherstudien GmbH
Qualitätstest.at
trend.
Test Gasanbieter
TESTSIEGER
Test 10/2021, im Test: Konditionen & Service
43 Anbieter, ögvs.at/6045

"Energy Efficiency Award 2021"
E1 Energy management

For the 2nd successive time:
1st place INTERNET ELECTRICITY SUPPLIERS
ÖGVS & trend / Electricity Supplier Test 21

E1 ENERGIE STEIERMARK

Market leader
PV and storage
E1 Heat and Energy

First **"Green Finance"** package of the **European Investment Bank** in Austria

Improvement of **GRESB** sustainability rating
92 of 100 points

KEY FACTS

ENERGIE
STEIERMARK

Renewable Energy

The company plans to invest around **one billion euros** in renewable energy projects till **2030.**

In this way, Energie Steiermark is making a significant **contribution to climate reversal** and the goals of **Mission2030**, as well as to overcoming the current crisis on the **labour market**.

KEY FACTS

ENERGIE
STEIERMARK

Renewable Energy

Photovoltaics...

- A total of around 230 million euros will be invested in expansion over the next few years
- Planned PV expansion of up to 300 MW by 2030
- Approx. 17,107 PV systems with an output of 241 MW fed into the grid by the end of 2020 - energy feed-in of 167 GWh
- We commissioned new systems at private companies that supply more than 6 million kWh of solar power in 2021 alone

Wind Power...

- Including the Sommeralm, Energie Steiermark has 18 wind turbines in operation
- Expansion plans: Wind power to 300 MW by 2030 - that means 100 wind turbines with 300 MW for 150,000 households
- Investment of around 320 million euros in wind power expansion over the next few years

KEY FACTS

ENERGIE
STEIERMARK

Renewable Energy

Hydro Power...

- Mur power plants in Gössendorf (in operation since 2012), Kalsdorf (in operation since 2013), Graz (in operation since 2019), Gratkorn (being implemented), Leoben (in planning)
- Operation of around 10 small power plants on the Mürz, Liesing, Feistritz and Raab rivers
- Various small hydroelectric power plants in planning

KEY FACTS

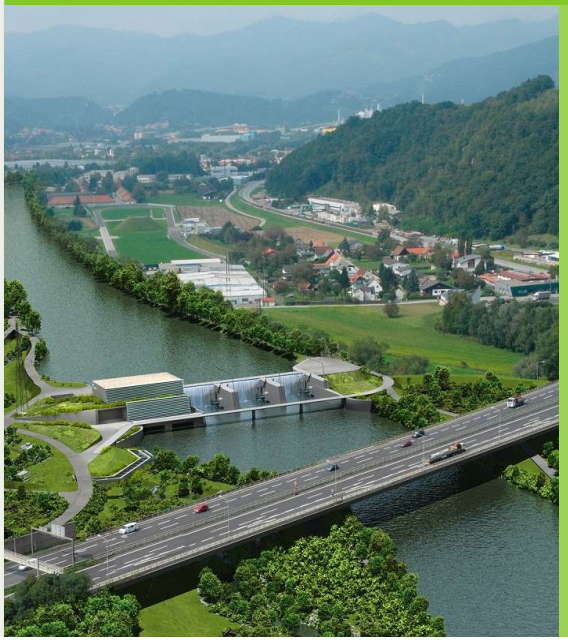
ENERGIE
STEIERMARK

Expansion
Renewable Energy

Current Projects

Plankogel Wind Turbine

- Official commissioning in **summer 2022**
- **Profit-sharing scheme** to be offered
- Green electricity for around **3,000 households** in the "Almenland" region
- Output of **3.6 megawatts** and total generation volume of around **10 million kilowatt hours per year**



Gratkorn Hydroelectric Power Plant

- New **joint power plant** of **Energie Steiermark** and **VERBUND**
- Covers the electricity needs of **15,000 households** with green energy
- **Construction** started in **2021** and **commissioning** planned for **2024**

KEY FACTS

ENERGIE
STEIERMARK

Expansion
Renewable Energy

Current Projects

GKB Photovoltaic Plant Karlschacht II in Bärnbach/Rosental

- Former GKB Bergbau slag dump in Rosenthal
- **Main assignments** placed in **2021**, **commissioning in winter 2022, Installation 2022**
- Over **20 hectares of collectors** provide electricity for more than **5,000 households**

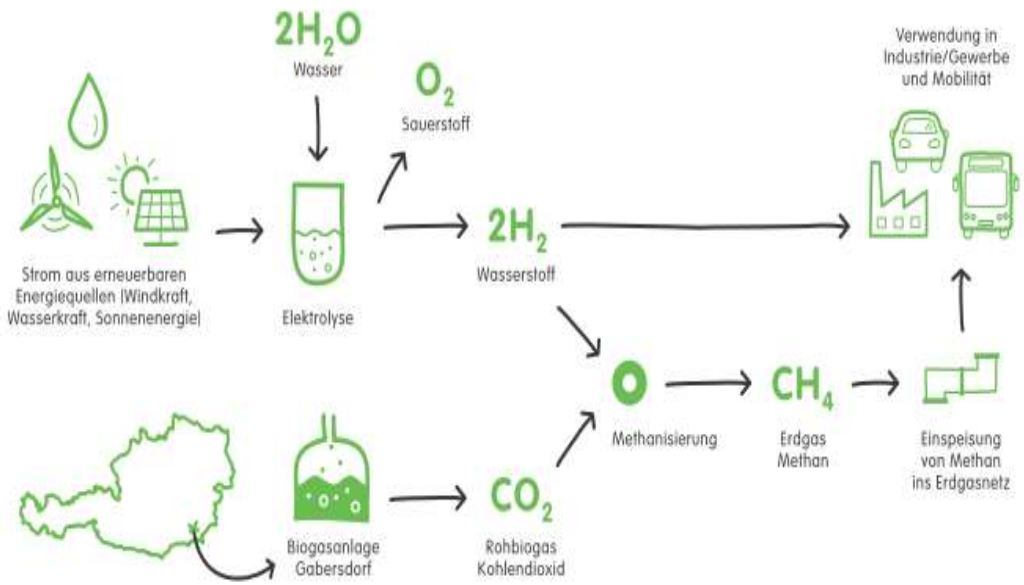
Photovoltaic Plant in Neudau

- **Installation 2022**
- The construction of an approximately **11-MWp PV open-space system** is planned on an agricultural area

KEY FACTS

ENERGIE
STEIERMARK

Hydrogen



Renewable Gas Field

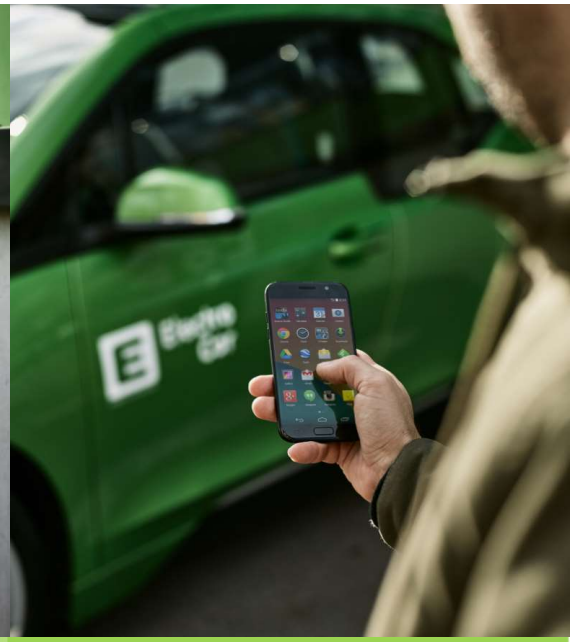
- Innovative **Power-to-Gas project**
- **Start of construction in the first quarter of 2022, commissioning in autumn 2022**
- **1 MW electrolysis output** (+ 1 MW from 2023)
- **250 tons of H2 production** per year (at full expansion)

2022 Start of the first "green" **hydrogen production** in Austria for the industrial market - cooperation with **Wolfram**

KEY FACTS

ENERGIE
STEIERMARK

E-mobility



- Energie Steiermark has built a **comprehensive**, **high-quality** e-charging network in Styria
- Thanks to the "**Panther**" Project, no household in **Styria** is **more than 15 kilometres** away from the nearest charging point
- Energie Steiermark currently operates **1,169 charging points**, 99 of which are **rapid charging stations** (DC)
- Over **4,000 users** of the Energie Steiermark **Mobility Card**

With more than **100 electric cars**, Energie Steiermark has the **largest fleet** of e-vehicles in the state

KEY FACTS

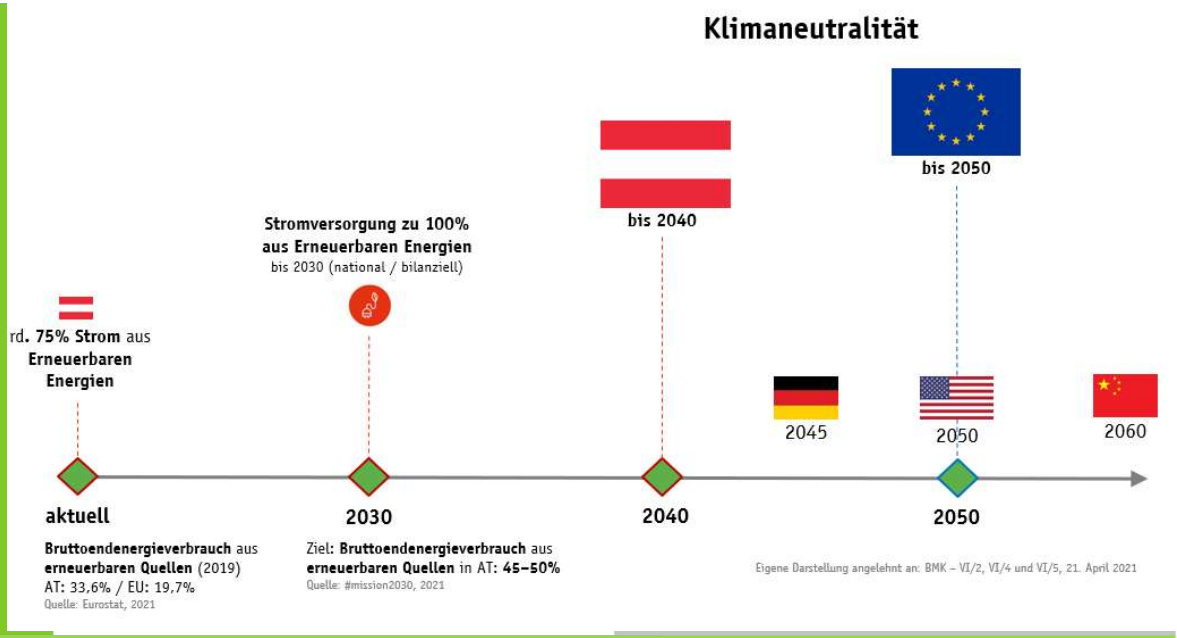
REEA

#mission2030
Die Klima- und Energiestrategie der Österreichischen Bundesregierung

EUROPEAN GREEN NEW DEAL

Clean energy for all Europeans

The **REEA** (Renewable Energy Expansion Act) represents a **milestone** in **achieving climate neutrality** in **Austria** by **2040**



EU Green Deal - climate neutrality by 2050

EU climate and energy targets 2030: **Reduction** of **GHG emissions** by at least **55% by 2030**, **increase** in the share of **renewable energies (RE) to** at least **32%**, **increase** in **energy efficiency** by at least **32.5%**

Government programme 2020-2024: Climate neutrality by 2040

National Climate and Energy Plan and #mission2030: **Share of renewables in total energy demand: 45-50%**, **100% total electricity consumption (national balance sheet) from RE**, increase in **energy efficiency** by 25-30%, **GHG emission reduction** by 36%

KESS 2030 (Climate & Energy Strategy of Styria): Share of **renewables in the total energy requirement** up to 40%, increase in **energy efficiency** by 30%, **reduction of GHG emissions** by 36%

Note: Austrian and Styrian targets are to be adjusted to the EU 55 target

ENERGIE STEIERMARK

KEY FACTS

REEA

The REEA creates a **modern legal framework**

The **main objective** is to cover 100% of the total electricity consumption from 2030 with RE nationally

Source: Federal Ministry for Climate Action - VI/2, VI/4 and VI/5, 21 April 2021

Main objective
100% electricity from RE by 2030

The **REEA** (collective law) follows the expiring **Green Electricity Act 2012** and primarily implements the **Renewable Energy Directive** (RED II, 2018/2001)

The REEA was passed on **07/07/2021** with a 2/3 majority in the **National Council**.

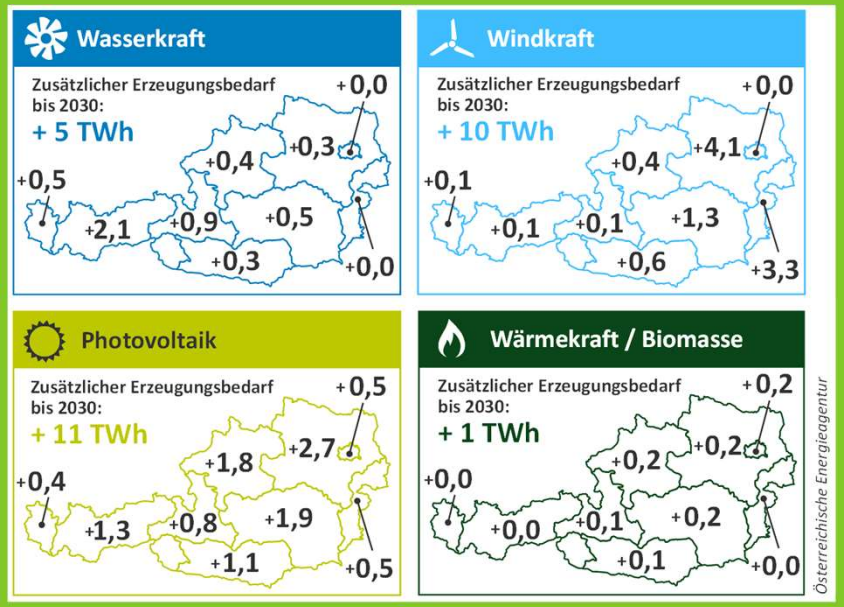
In **January 2022**, as a result of objections from the EU Commission, an **amendment to the REEA was decided**.

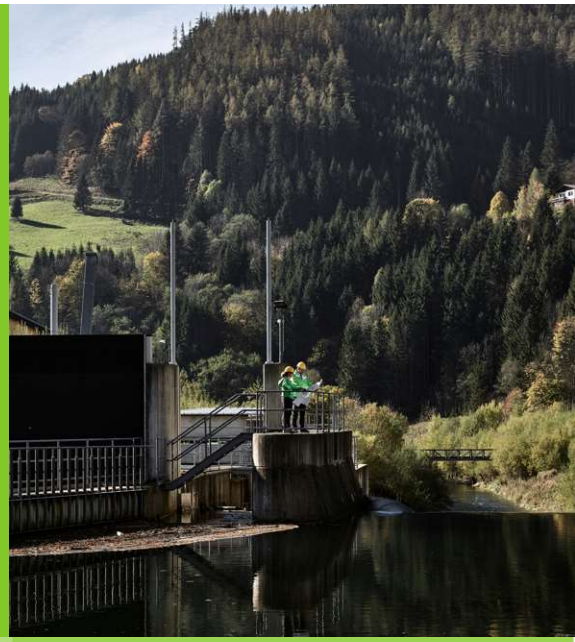
Implementation of the relevant **regulations**

KEY FACTS

REEA

The **intensified expansion of renewables and infrastructure** is required to **achieve** the 2030 **targets**





Investments of **70 billion euros** are required for the **expansion** of **renewable energies** and the **associated infrastructure** in **Austria** by **2030**

43 billion euros of this alone are for the **expansion** of **renewable power generation** and **grids** (Energieinstitut der Wirtschaft, 2022)

- **Accelerating** and **increasing the efficiency** of **EIA procedures**
- **Joint** potential-based **efforts** for the **expansion** of renewable energy sources
- **Future-proof regulation** and **market design**

ENERGIE STEIERMARK

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