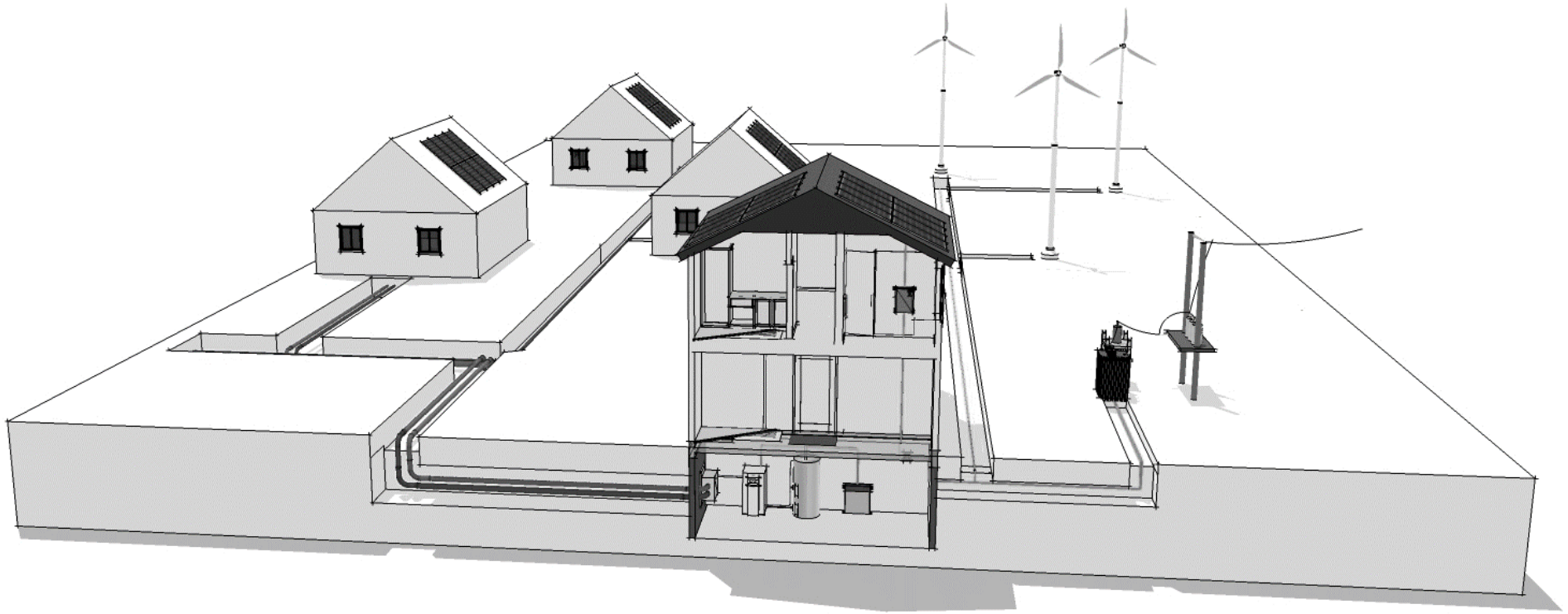
THE POTENTIAL OF SMALL WIND TURBINE INTEGRATION IN RESIDENTIAL BUILDINGS COMPLEMENTING PV AND HEAT PUMP OPERATION



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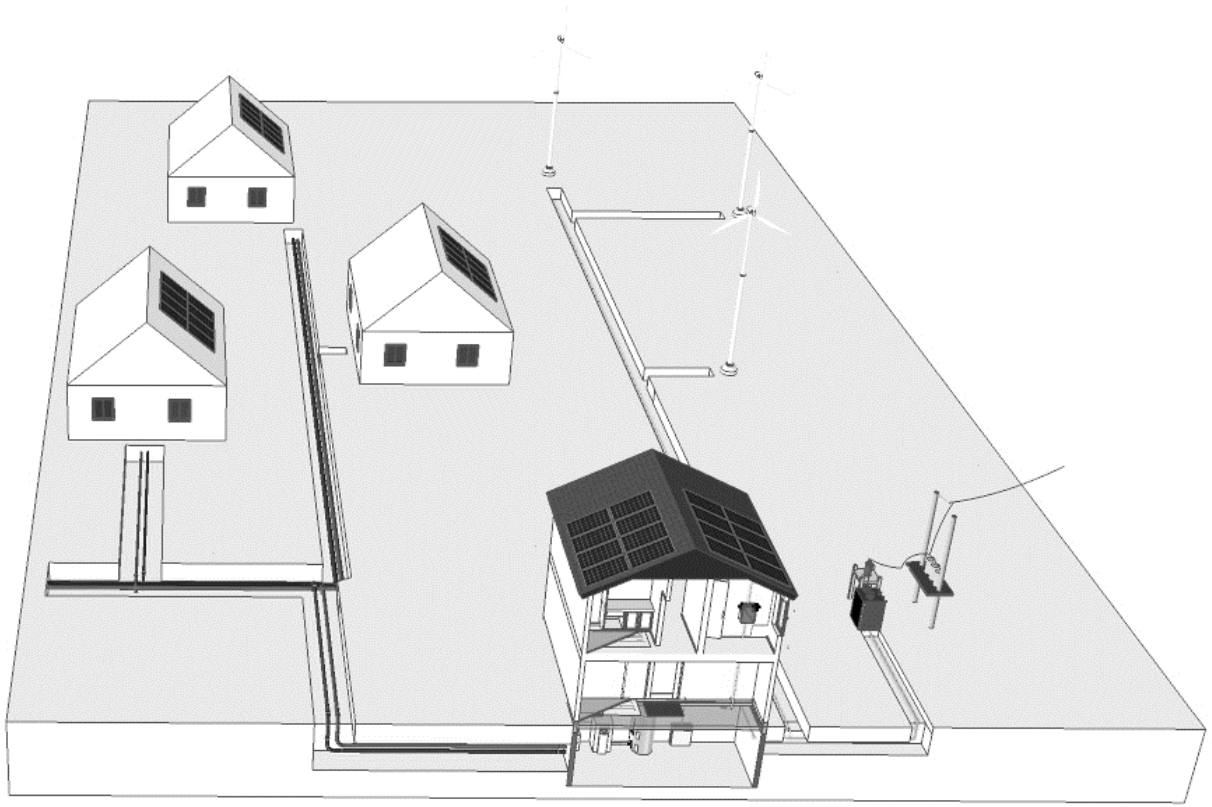
Overview

- The Windy Cities Graduate Research Kolleg
- Introduction to the pilot site
- The regarded building systems in detail
- Seasonal storage on formic acid basis
- Modelling approach
- Simulation study and results



Cooperative Graduate Research Kolleg: Windy Cities

- Focuses on investigations of the **economic use of small wind turbines for local distributed power generation in urban areas**

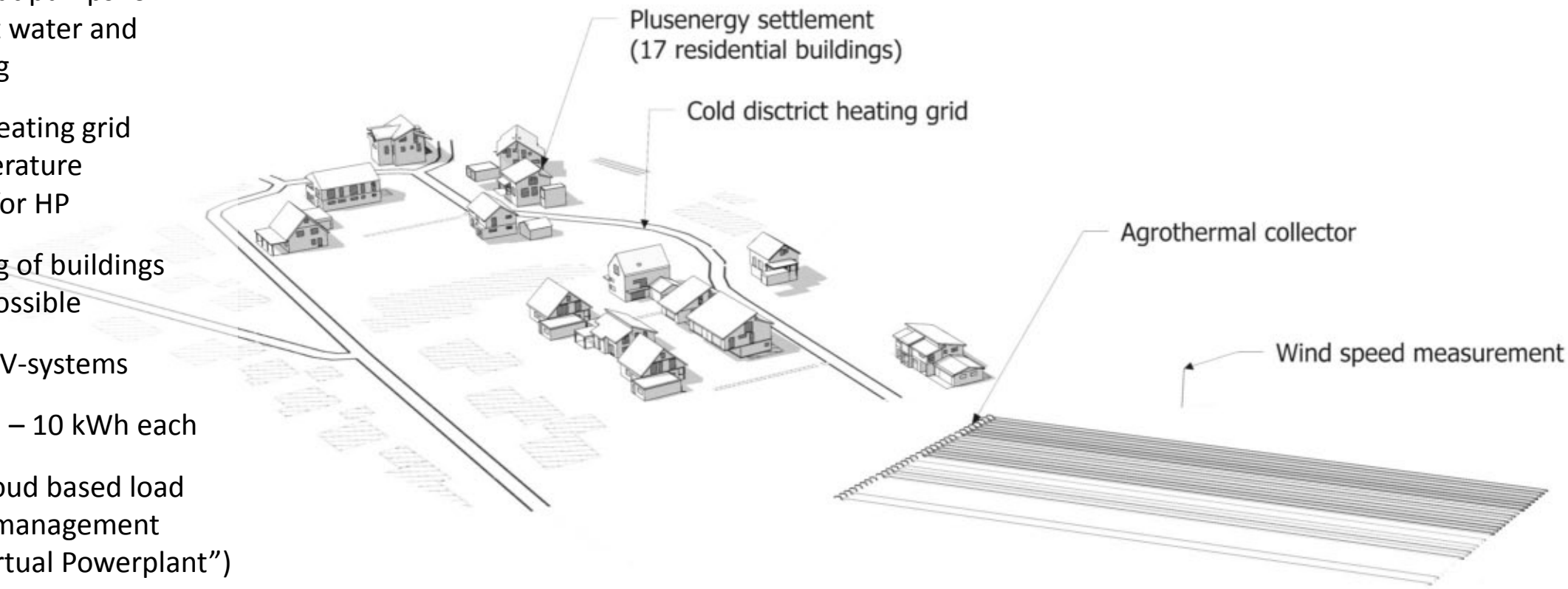
- Interdisciplinary approach including 12 projects for simulation and visualization: development of new energy storage technologies, testing of wind turbine prototypes and intelligent load management

- Focus of this project: Load management regarding power2heat systems in residential building systems and building clusters → Work related to the Horizon 2020 research project SIM4BLOCKS (www.sim4blocks.eu)

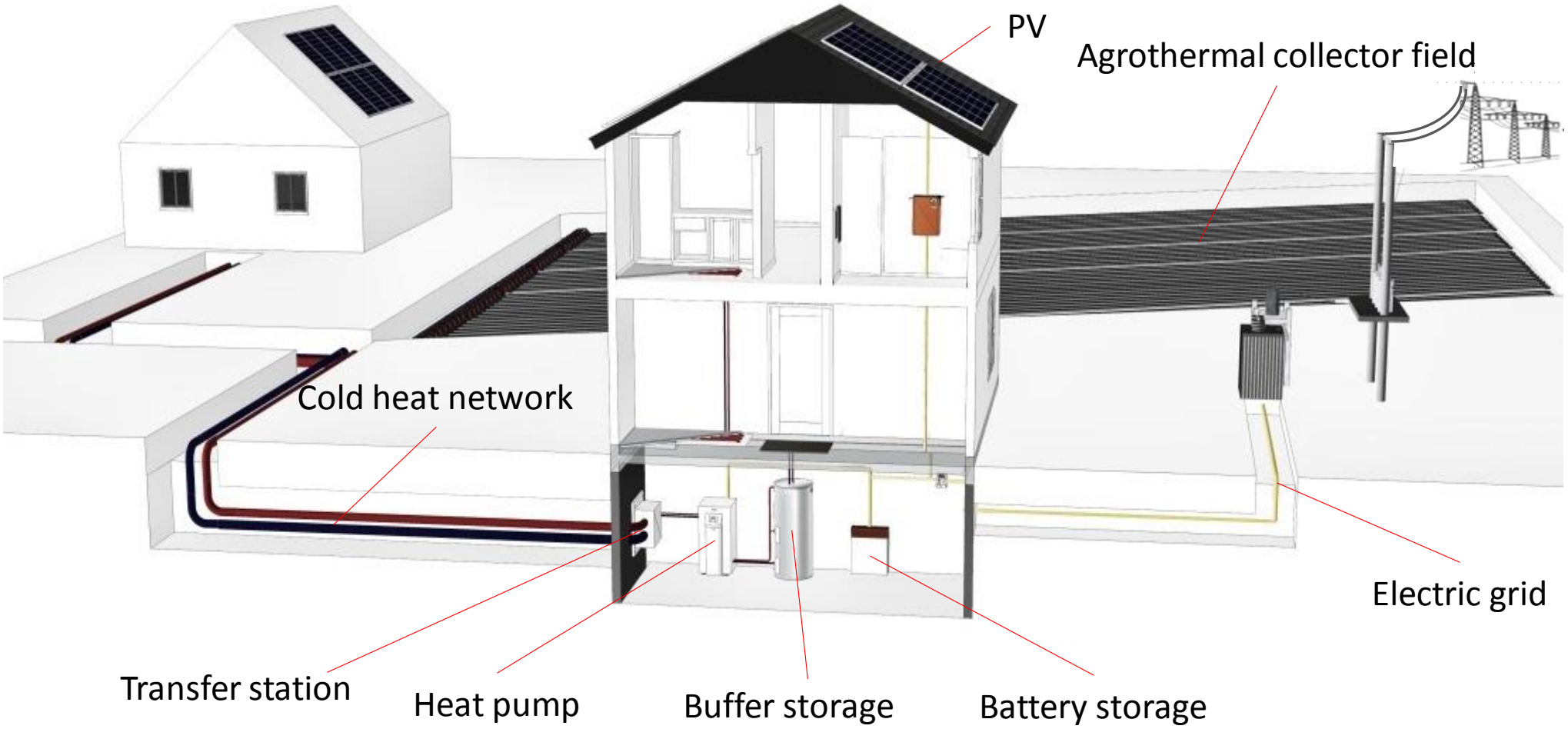
The Wüstenrot Pilot Site: Systems on Cluster Level

Details:

- Decentral heat pumps for domestic hot water and space heating
- Cold water heating grid as low temperature heat source for HP
- Direct cooling of buildings in summer possible
- 7 – 10 kWp PV-systems
- 6 Batteries, 5 – 10 kWh each
- Intelligent cloud based load and storage management possible (“Virtual Powerplant”)



The Wüstenrot Pilot Site: Systems on Building Level



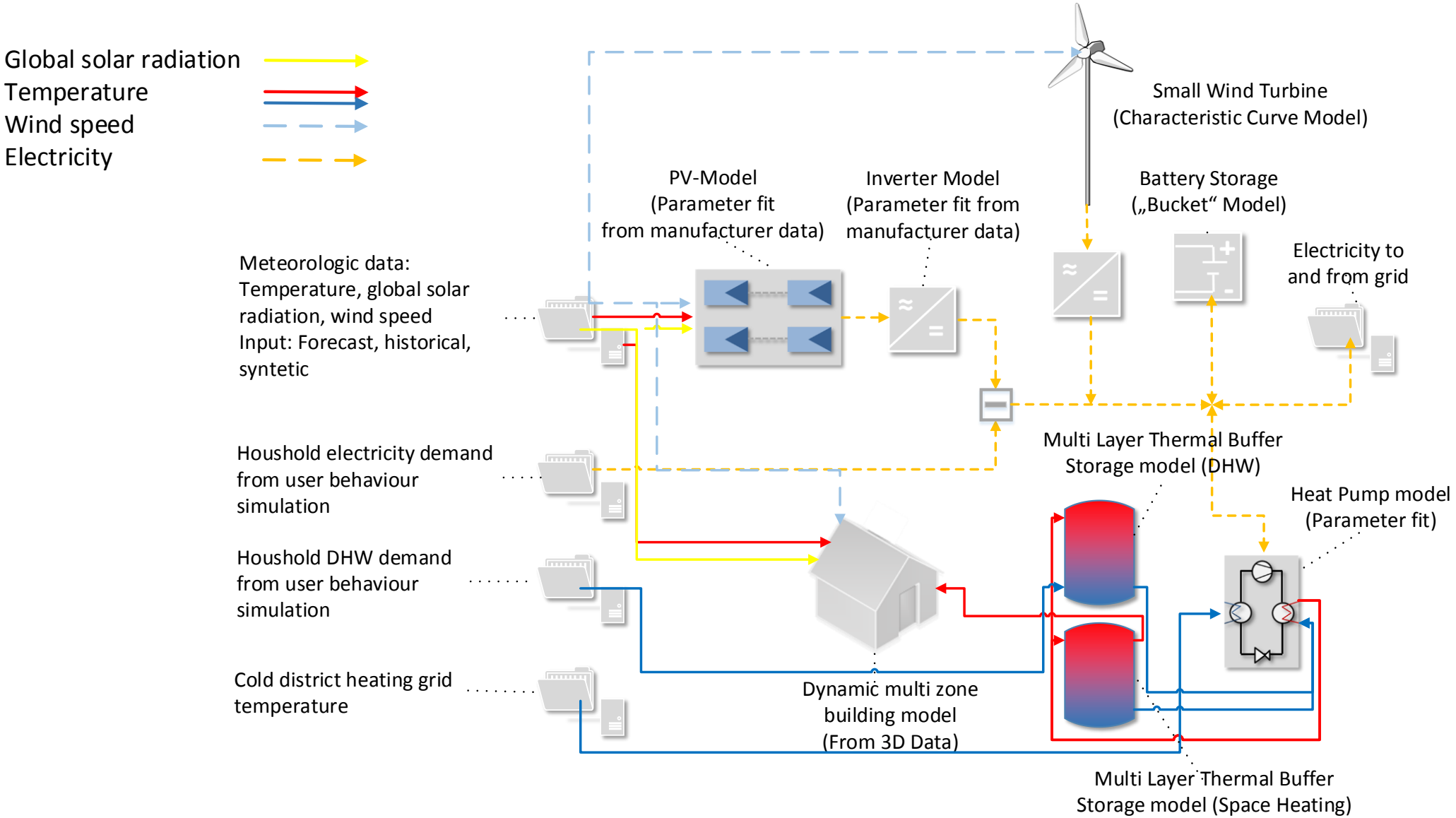
→ Monitoring of all the relevant building energy flows in high resolution

Building and System Specifications

Building Type	Detached residential building; 2 flats
Insulation Standard	Build in 2013 according to German „KfW 70“ standard (~ 60 kWh/m²a)
Building Size	285 m² of living area
Heat Pump	Waterkotte Modell DS 5023.5Ai, 22.2 kW thermal output / 4.5 kW electrical consumption
Thermal Buffer Storage	Heating 1000l; DHW 400l
Battery Storage	Liacon; 5 kWh; 1C
PV Orientation	58.4 m² (48 modules) orientation 180°, tilt 15°; 49.5 m² (40 modules) orientation 0°, tilt 15°
PV Manufacturer and Model	Solar Frontier Typ SF155-L; 13,64 kWp
Wind Turbine Manufacturer and Model	Aeolos-V; 5 kW

The (White Box) Simulation Model in Detail

Realized in the simulation environment INSEL and validated



(Seasonal) Hydrogen Energy Storage Research

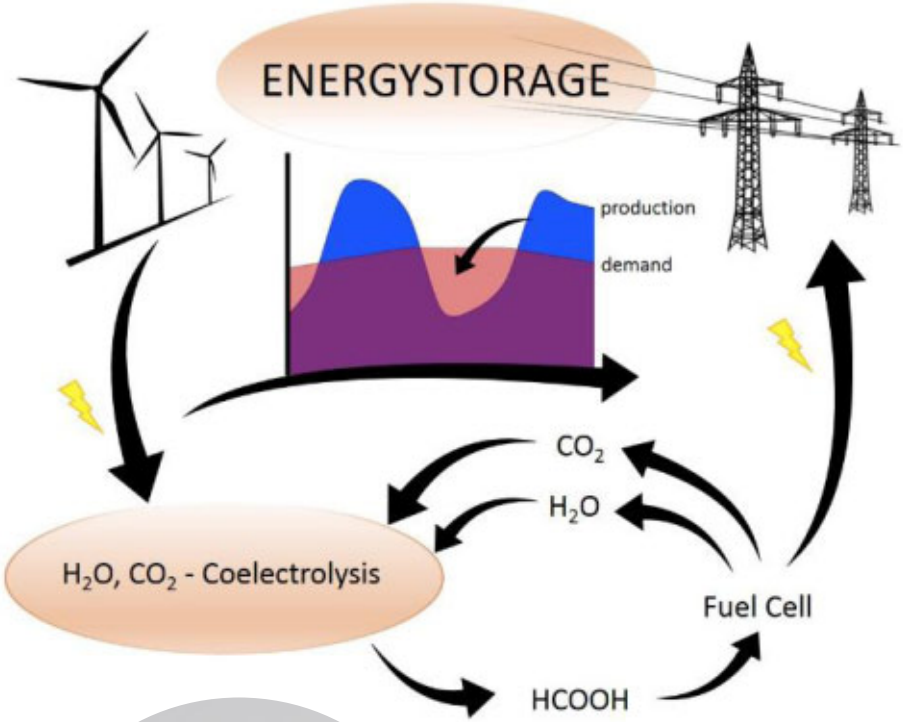
- To increase the overall energy self-consumption an additional storage system is examined (polymer electrolyte membrane electrolyzer stack and fuel cell)
- A lot of research has been conducted on high pressure hydrogen storage systems → an alternative is to store hydrogen in chemical bonds → one suitable substance is formic acid

→ FA is non-toxic and environmental harmlessness

→ Its liquid character under ambient conditions makes FA easy to use with a **good long-term stability, making it predestinated for seasonal storage**

→ FA can be formed catalytically from carbon dioxide and hydrogen under moderate reaction conditions

→ FA can be catalytically dehydrated to release hydrogen and used directly in so called Formic Acid Fuel Cells, which are currently subjects of research projects. On the other hand, hydrogen can be released from FA and used in conventional fuel cells



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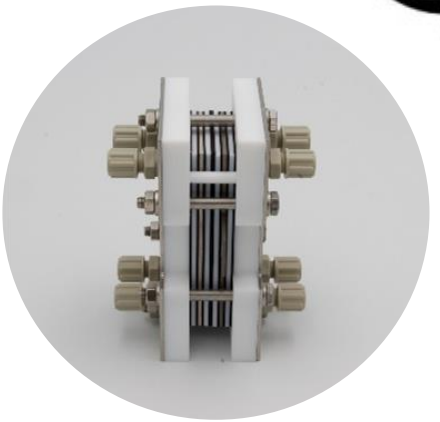
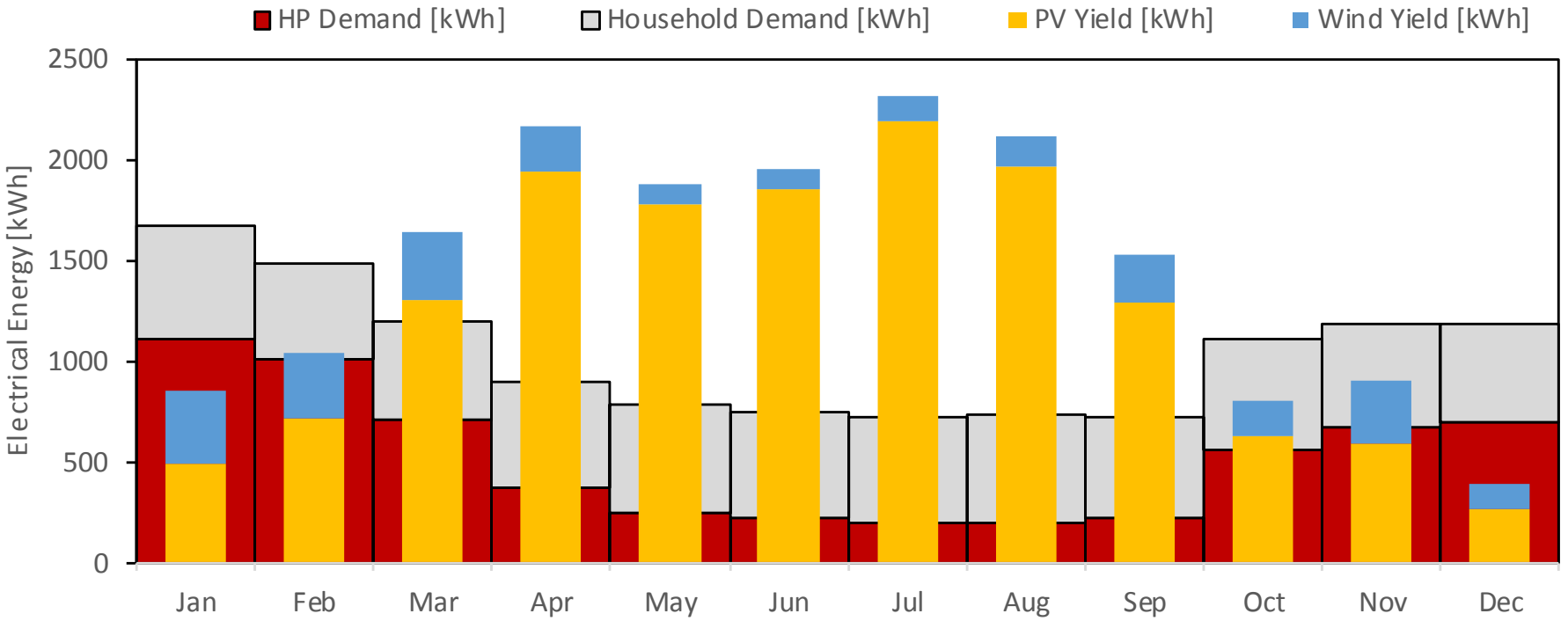


Results (General)

- Assumption: **wind electricity is used first** due to lower feed in tariff (0.071 EUR/kWh vs 0.123 EUR/kWh)
- Up to 65 % of building autarky can be reached including heating and household electricity demand
- The additional wind turbine has a low impact on PV self-consumption with an average reduction of 16 %
- During the winter heating period almost the entire heating demand can be provided by the wind and PV yield
- There is a large excess production during the summer months mainly due to the seasonal differences in PV generation



Results (System Size Specific)

- Self-consumption and autarky was examined for different battery sizes (5 kWh, 10 kWh, 20 kWh) for solely PV electricity generation and for electricity generation from PV and a small 5 kW wind turbine
- Ratio drop from 36 % to 31 % with a wind system specific self-consumption ratio of 83 % for a 5 kWh battery
  from 45 % to 39 % with a wind system specific self-consumption ratio of 87 % for a 10 kWh battery
  from 53 % to 46 % with a wind system specific self-consumption ratio of 90 % for a 20 kWh battery
- In the worst case (5 kWh battery), the number of battery cycles would increase by 20 %
  → decrease in battery life

	Qel Wind to Grid [kWh/a]	Qel PV to Grid [kWh/a]	Qel Total to Grid [kWh/a]	Qel from Grid [kWh/a]	Qel Wind Yield [kWh/a]	Qel PV Yield [kWh/a]	Qel HP [kWh/a]	Qel Household [kWh/a]	Battery Cycles	PV Self-Consumpt.	Wind Self-Consumpt.	Building Autarky
Only PV, 5 kWh Storage	0	7988	7988	8066	0	12462	6204	6239	356	36%	-	36%
5kW Wind, 5 kWh Storage	426	8645	9071	6509	2574	12462	6204	6239	441	31%	83%	48%
Only PV, 10 kWh Storage	0	6860	6860	7072	0	12462	6204	6239	294	45%	-	45%
5 kW Wind, 10 kWh Storage	341	7569	7910	5505	2574	12462	6204	6239	337	39%	87%	57%
Only PV, 20 kWh Storage	0	5828	5828	6182	0	12462	6204	6239	197	53%	-	53%
5kW Wind, 20 kWh Storage	265	6677	6942	4683	2574	12462	6204	6239	217	46%	90%	65%

Results (Seasonal FA Based Hydrogen Storage)

- For this study the efficiency of the fuel cell is considered to be 50 % and the efficiency of the dehydrogenation 90 % (Confirmed by experimental studies)
- For full self-consumption 6.120 kWh and for full autarky 4.330 kWh of electricity have to be stored
- Using chemical seasonal storage possibilities based on a PEM-electrolyzer, hydrogen storage in the form of FA and a PEM-Fuelcell for full self-consumption of wind and PV electricity, 7.683 liter of FA have to be stored
- For solely 100 % of electrical autarky 5.436 l of FA have to be stored

Outlook

- Further investigations will be carried out on the blocks of buildings level → focus on power and electricity market interaction (flexible electricity tariffs, reserve power markets)
- Dynamic electrolyzer model will be included
- Optimization routines will be included for the daily operation (either rule based or GA – both approaches exist)
- It is planned to include results regarding optimized building system operation into the buildings real system schedule

Thank you very much!

www.windycities.de | www.envisage-wuestenrot.de | www.sim4blocks.eu