Temporal Resolution for Capturing Buildings' Energy Flexibility

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Introduction

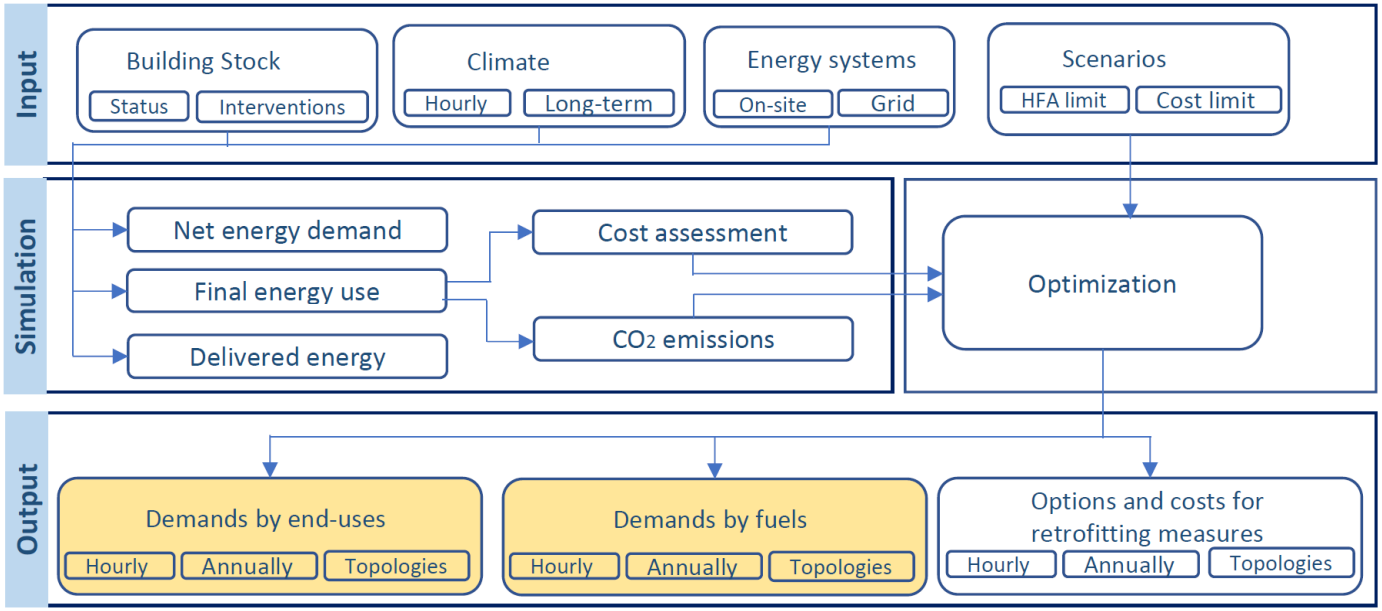
- EU aims to achieve climate neutrality by 2050 [1]
- The GHG emission levels must be reduced substantially to achieve this target [2]
- The building stock is responsible for 28% CO_2 emissions globally [3]
- Many buildings have ability to be energy flexible [4]
- Energy flexibility is a potential solution for balancing intermittent renewables [4]
- We aim to identify how to better capture the energy flexibility of buildings while assessing energy transition

Methodology

- Assess the impact of Time Resolution (TR) on energy system analysis
- Energy system of the residential sector of Eskilstuna (municipality in southern Sweden) is considered
- Employs ECCABS model and TIMES-City model to identify the impact of TR
- ECCABS model simulates the buildings' energy demand profile
- This data from ECCABS model is fed to TIMES-City model
- TIMES-City model is used to assess the least-cost solution for meeting the energy demand over model horizon
- TIMES-City model is run with different temporal resolutions (12 and 72 slices per year)
- Finally, the influence of Time Resolution on energy system analysis is assessed

ECCABS MODEL

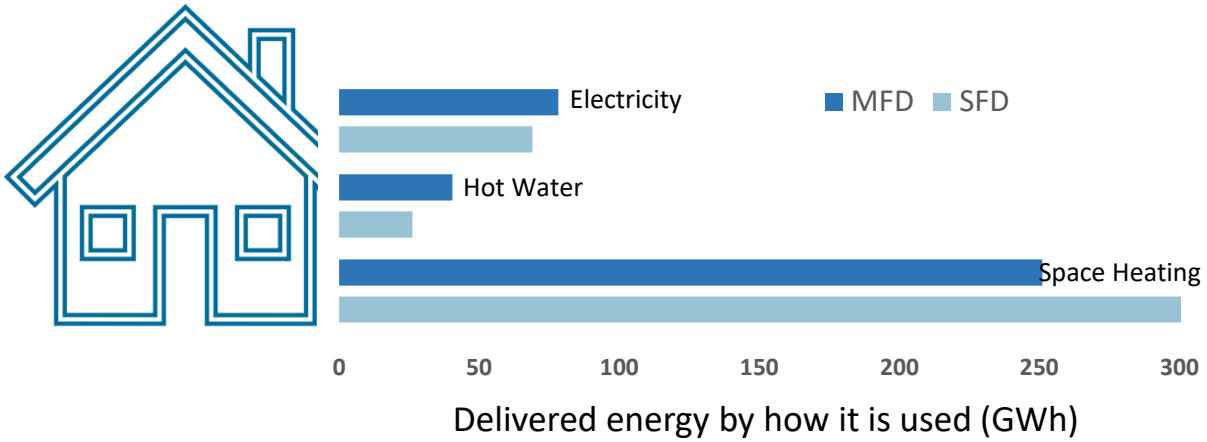
- **ECCABS** Model - Energy, Carbon and Cost Assessment of Building Stocks ECCABS model is used to simulate the buildings energy demand profile
- Model Structure described in Mata et al (2020) :
  - Simulink model - includes the simulation & optimization modules and solves the energy balance for the buildings and provides the energy demand
  - Matlab Code - handles the input and output data from the Simulink model and extends the results to the building stock



Structure and workflow of ECCABS Simulation Model

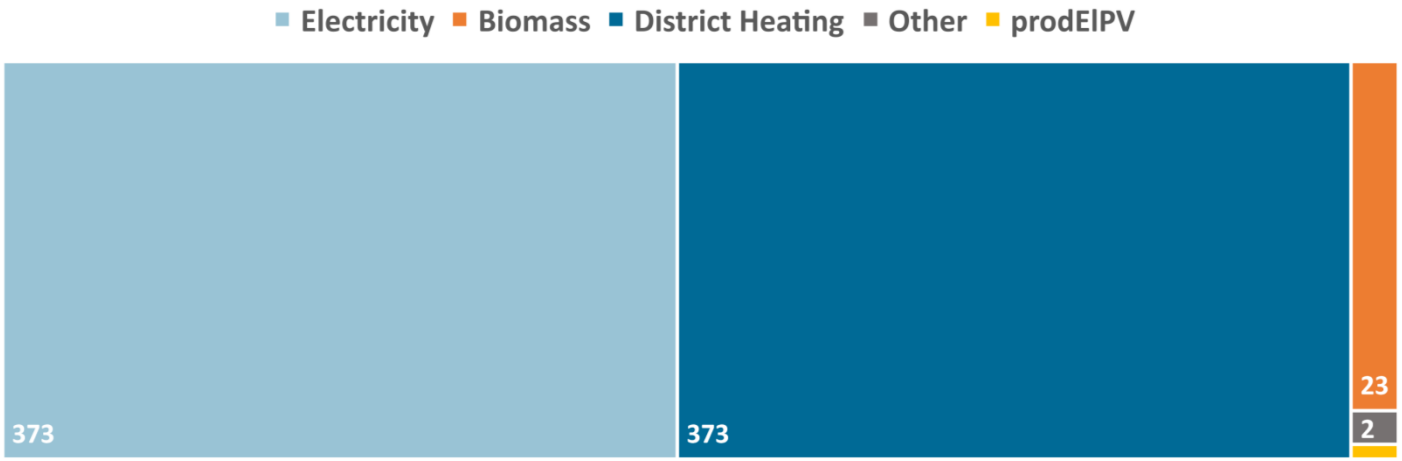
Mata, É ., Wanemark, J., Österbring, M., & Shadram, F., (2020) Ambition meets reality –Modeling renovations of the stock of apartments in Gothenburg by 2050. *Energy and Buildings,* 223, 110098. https://doi.org/10.1016/j.enbuild.2020.110098.

ECCABS Modeling Results



Delivered energy by how it is used (GWh)

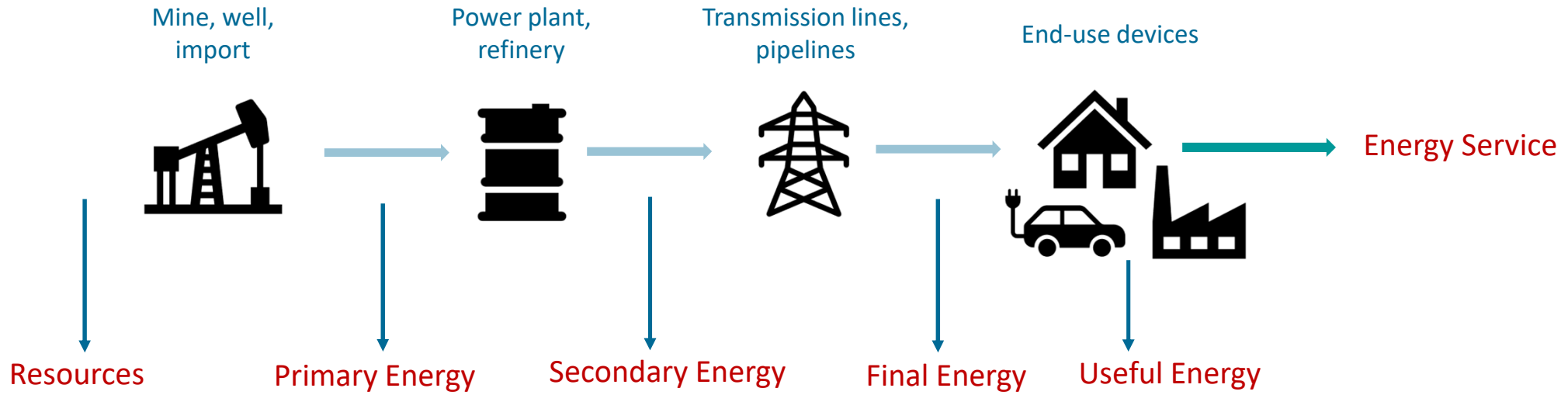
- Simulated energy demand for residential building stock of Eskilstuna for base year (2018)
- The output from ECCABS model includes demands by end-uses and demands by fuels



Delivered energy by energy commodity (GWh)

TIMES-City MODEL

- TIMES – The Integrated MARKAL-EFOM System - An energy system optimization modelling framework
- TIMES-City generic model was developed within the SureCity EU EraNet project as a tool for enabling cities to achieve their sustainability targets. The model is described in Krook-Riekkola et al (2018).
  - By assessing least-cost solutions for meeting energy demand in including different constraints
  - The model encompasses the possibility to describe the different steps from resource extraction, transformation, transport, distribution, and energy conversion to the provided energy services
  - Large modeling horizon is generally considered for analysis (base year – 2018 to 2050)
  - Different Time Resolutions (TRs) can be considered for analysis



Krook-Riekkola, A., Unluturk, B., Forsberg, J., Simoes, S., Dias, L., Pardo-García, N. (2018) Outline of the City-Level Modeling Framework. http://ltu.diva-portal.org/smash/get/diva2:1547605/FULLTEXT01.pdf.

TIMES-City Modeling Details (1/2)

Modeling Parameters:

For analyzing the impact of TRs on choosing the technology mix, energy sources and future investment decisions,

- Different TRs are defined
- Demand growth is calculated
- Different price ranges are used for district heating & electricity

➢ Time Resolution

12 TR	72 TR
Year is divided into 12 time slices	Year is divided into 72 time slices
4 seasons with day, night and peak	12 months with weekdays & holidays and day, night and peak
Average electricity price calculated for each slice from hourly electricity price	Average electricity price calculated for each slice from hourly electricity price

➢ Demand (exogenous) growth rate

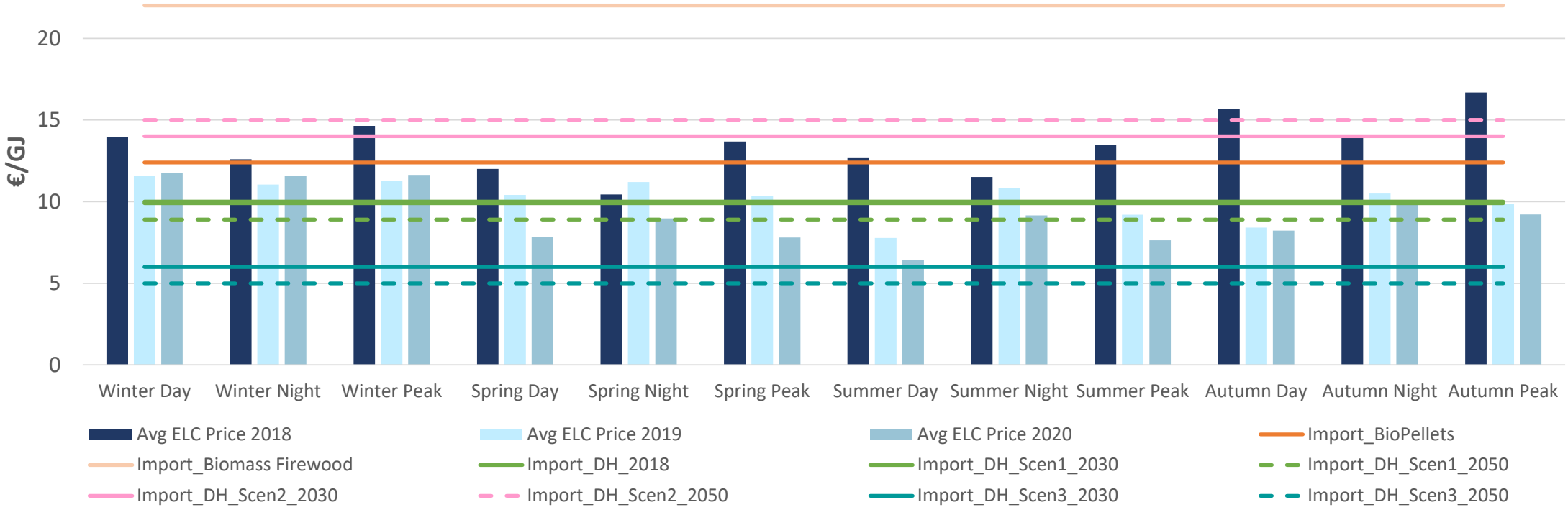
Parameters	Growth rate (%/year)		
	High	Medium	Low
Socio-economic evolution (GDP/capita)	3.80 %	1.60 %	0.80 %
Population evolution (number of inhabitants)	1.15 %	1.00 %	0.85 %
Inhabited residential buildings variation (number of m2)	1.65 %	0.82 %	0.41 %

TIMES-City Modeling Details (2/2)

- Electricity prices in base-year are based on historical hourly prices in Nordpool
- For years 2030 & 2050 its based on Balmorel model results
- Below graph shows the electricity prices for 12TR

District heating (DH) prices are assumed to be constant for all TR and are varied in a sensitivity analysis:

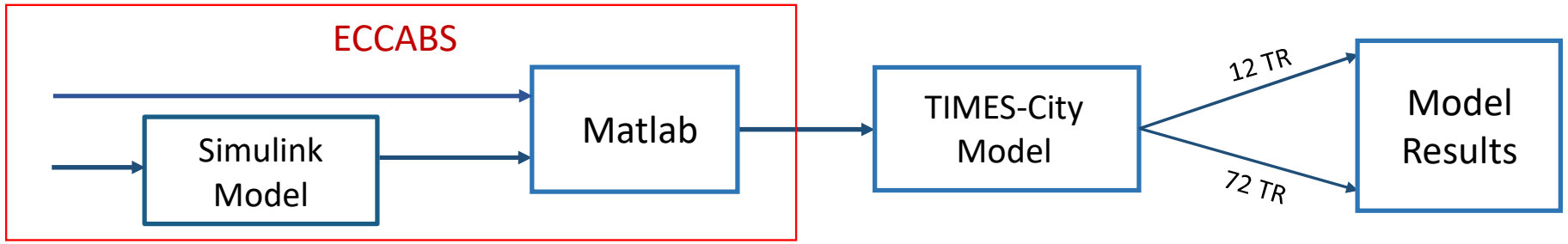
- Scenario 1: DH price in the range of Electricity prices
- Scenario 2: DH price > Electricity prices
- Scenario 3: DH < Electricity prices



Model Comparison

	TIMES-City	ECCABS
Aim of the model	Long-term energy planning	Long-term energy demand perspective
Kind of model	Techno-economic ESOM of the comprehensive energy system, including GHG and air pollutants	Energy, Carbon and Cost Assessment for Building Stocks
Methodology	Optimization (LP, cost-minimizing, dynamic)	Simulation
Model Structure	Demand of energy-intensive services: Provided exogenous / Supply: Modelled endogenously	Physical heating flows
Spatial resolution	8 buildings categories in residential sector	8 different building archetypes
Temporal resolution (TR)	12 and 72 slices per year	8760 slices per year
Time-horizon	2018-2050 (5- & 10-year intervals)	One year (2018)
Cost inclusion	All energy related cost	Not applicable in the study

Linking Models

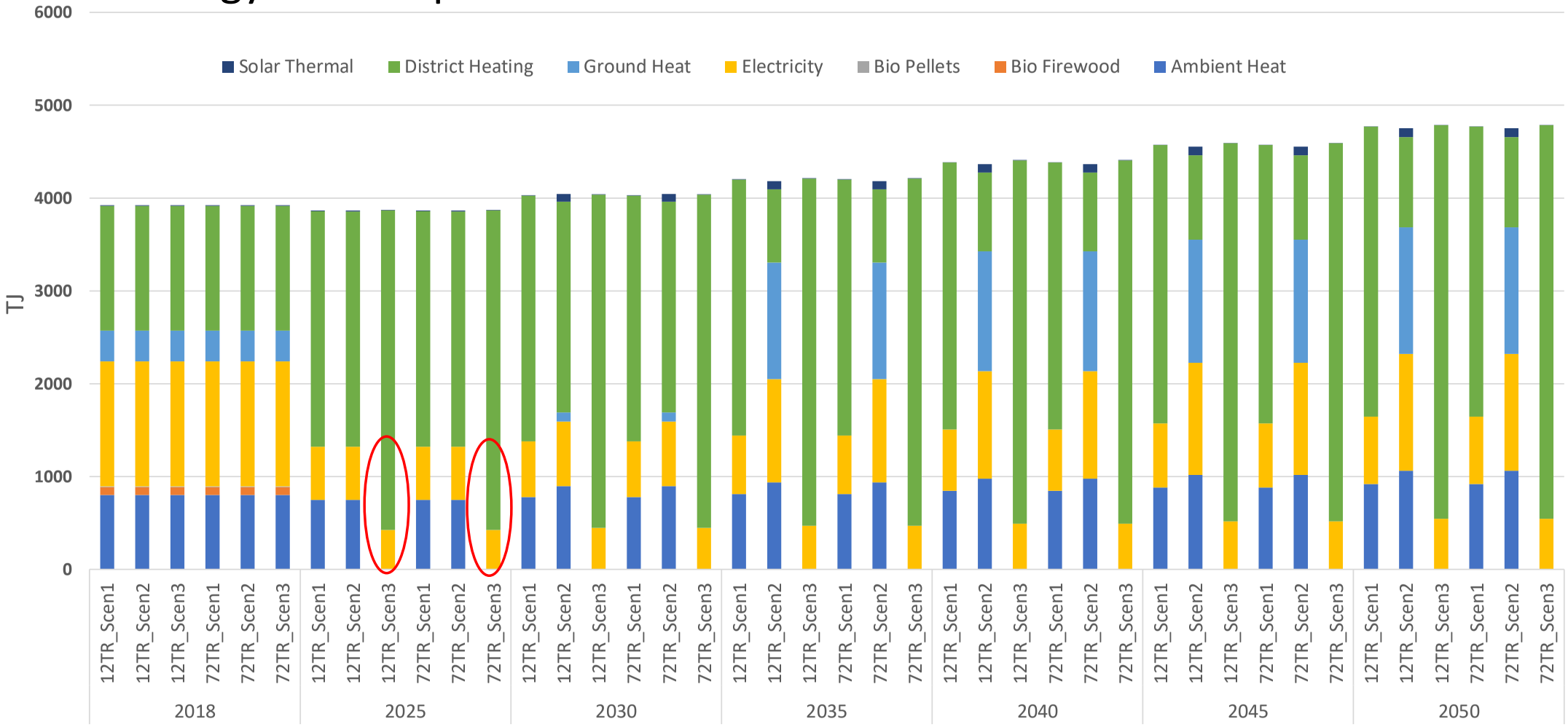


- The developed ECCABS model is used to tune the building stock characteristics in the TIMES-City model
- To align the two models, the residential building stock in TIMES & ECCABS model are aggregated into 8 different types based on area/size, type of heating system, and occupancy as below

single family buildings connected to district heating (DH)	multifamily buildings less than 5 floors connected to DH
single family buildings heated with heat pump (HP)	multifamily buildings less than 5 floors heated with HP
single family buildings heated with other sources (boilers, direct electricity, etc.)	multifamily buildings more than 5 floors connected to DH
multifamily buildings more/less than 5 floors heated with other sources	multifamily buildings more than 5 floors heated with HP

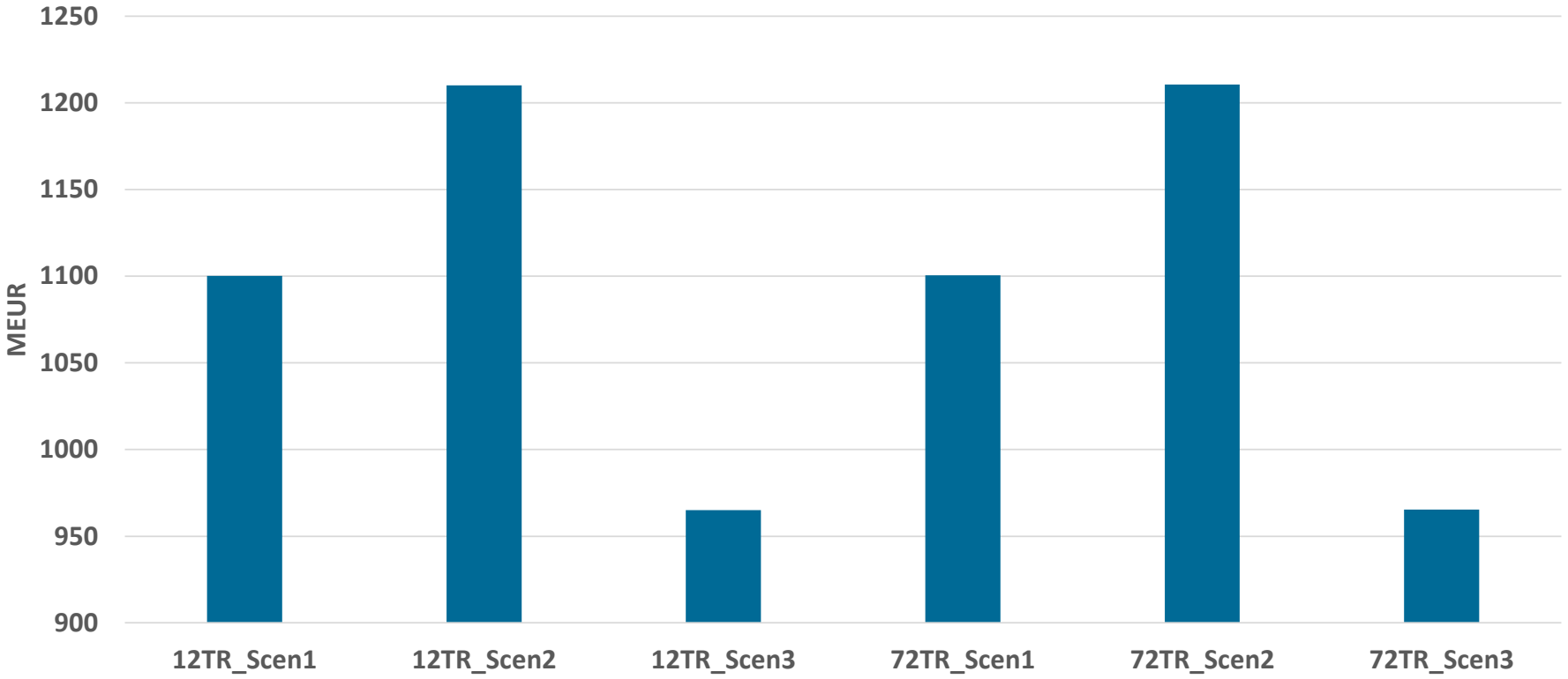
Results (1/2)

Final Energy Consumption



Results (2/2)

System Cost for the residential sector of the city of Eskilstuna



Conclusion

- Lower System cost at lower Time Resolution
- Aggregation of hourly electricity prices (8760 time slices) into lower time resolution (12 time slices) results in higher deviations
- Preliminary results show that Time Resolution has less impact on energy system analysis

Future Work

- TIMES-City Model for Eskilstuna is in initial phase
- Analyzing to understand more on model behavior at lower and higher resolutions
- Scope to increase the time resolution

References

[1] European Commission (2018) 2050 long-term strategy. https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en (Accessed on 04 April 2022)

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[3] Architecture 2030 (2021) Why the building sector ? https://architecture2030.org/why-the-building-sector/

[4] Grønborg, J., Azar, A., Lopes, R., Lindberg, K., Reynders, G., Relan, R.,and Madsen, H. (2018) Characterizing the Energy Flexibility of Buildings and Districts. *Applied Energy,* 225, 175–82. https://doi.org/10.1016/j.apenergy.2018.05.037.

Thank you

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Questions

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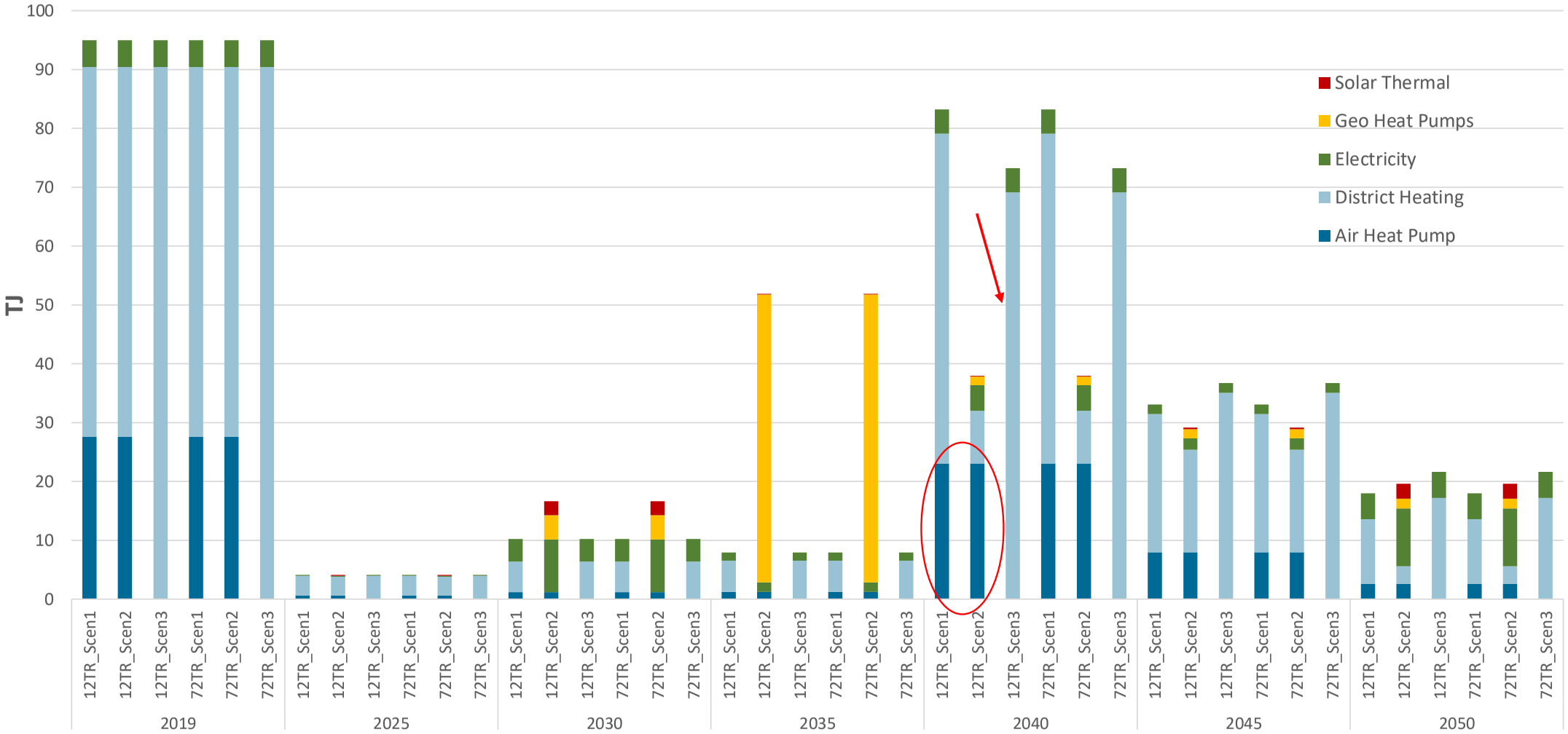
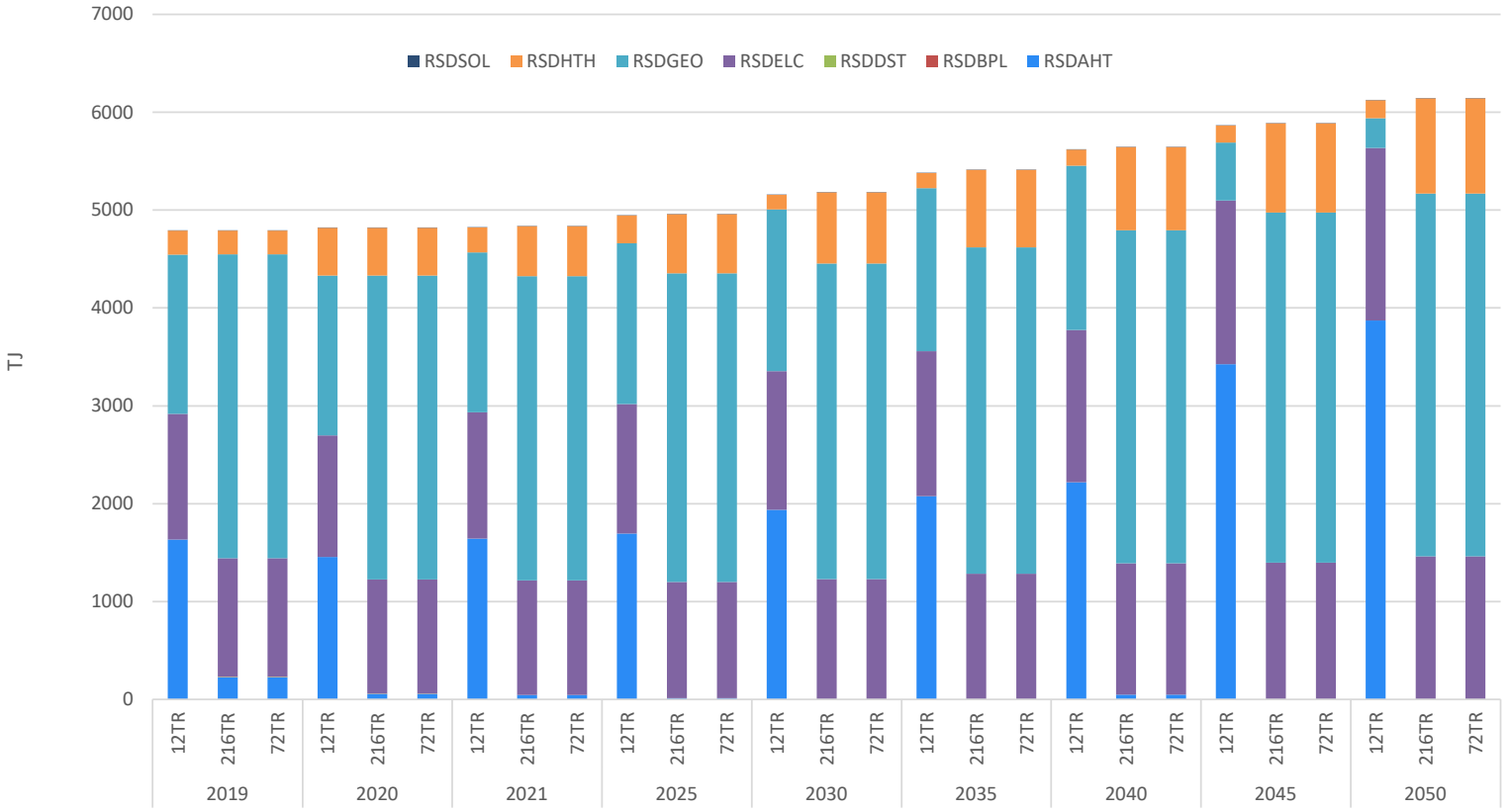
Results (3/3)

Future Investments

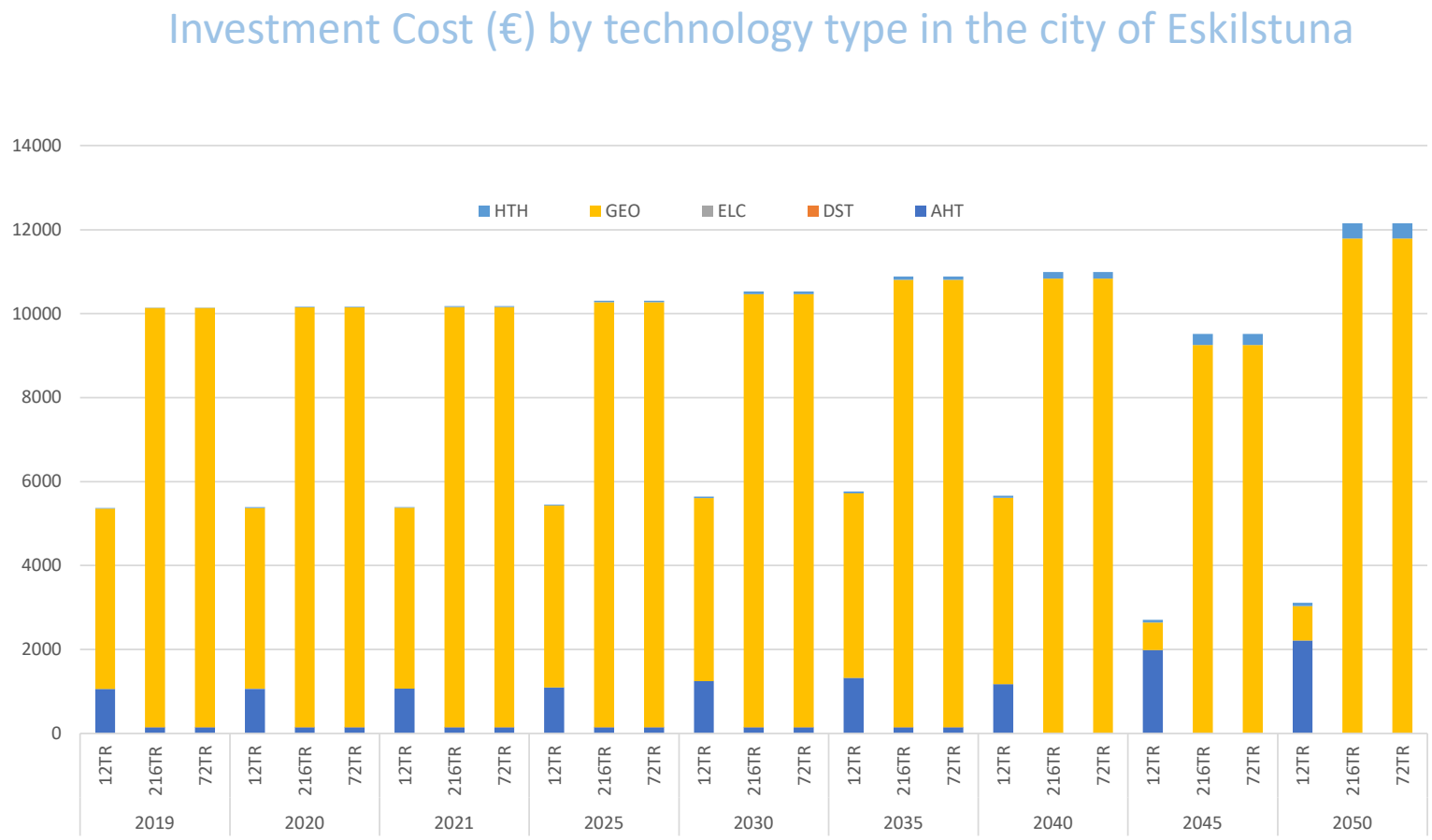


Preliminary Results

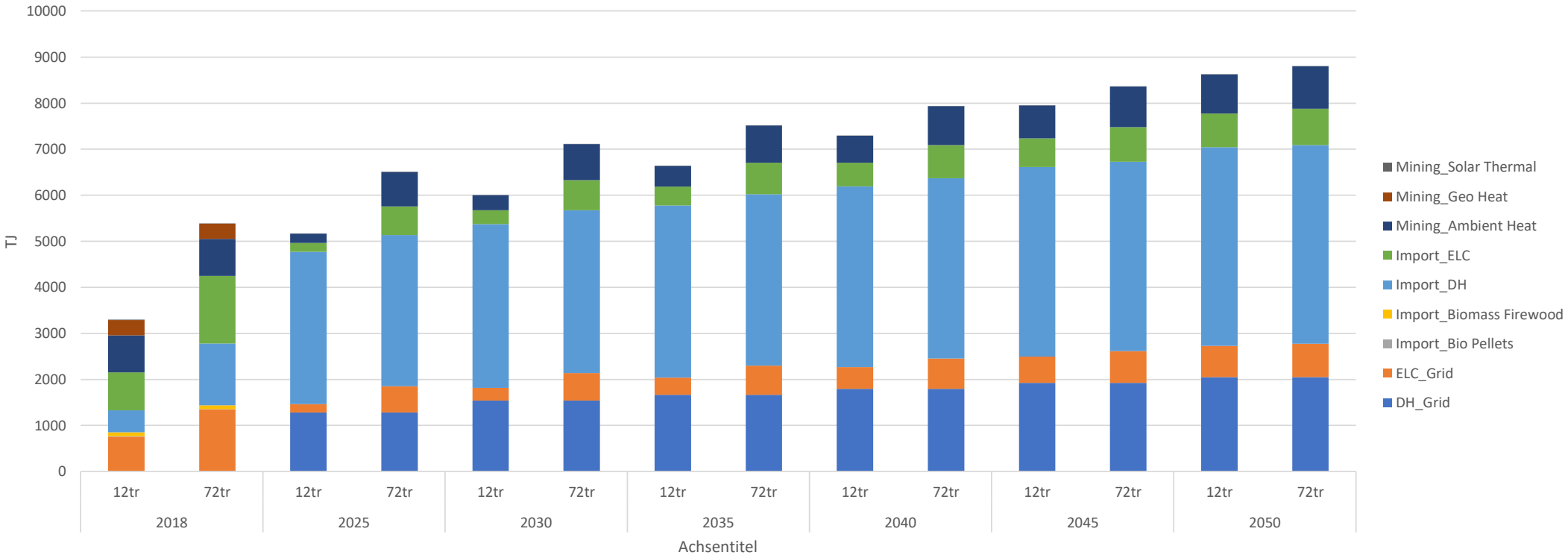
Final energy demand (TJ) by fuel type in the city of Eskilstuna

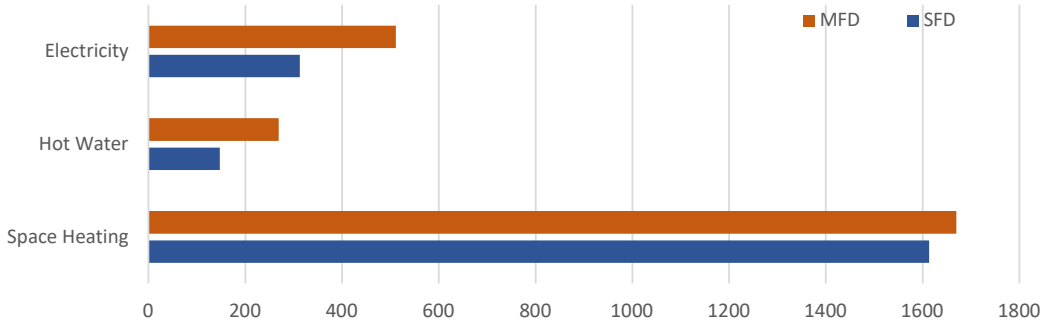


RSD-residential;
SOL-solar;
HTH-district heating;
GEO-geothermal;
ELC-electricity; DST-diesel;
BPL-bio pellets; AHT-ambient heat

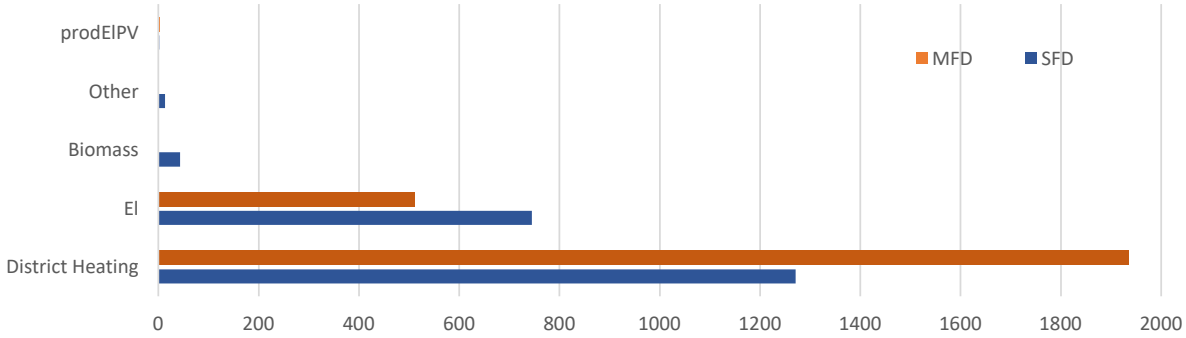

Investment Cost (€) by technology type in the city of Eskilstuna
14000
12000
10000
8000
6000
4000
2000
0
HTH
GEO
ELC
DST
AHT
12TR
216TR
72TR
2019
2020
2021
2025
2030
2035
2040
2045
2050

Supply


10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
TJ
12tr
72tr
2018
2025
2030
2035
2040
2045
2050
Achsentitel
Mining_Solar Thermal
Mining_Geo Heat
Mining_Ambient Heat
Import_ELC
Import_DH
Import_Biomass Firewood
Import_Bio Pellets
ELC_Grid
DH_Grid



Delivered energy demand by end use (TJ) for the base year



Delivered energy demand by fuel type (TJ) for the base year