Flex4RES

RĪGAS TEHNISKĀ UNIVERSITĀTE

Solar DH system sustainability and flexibility increase forecast via power-to-heat technology integration. System dynamics approach

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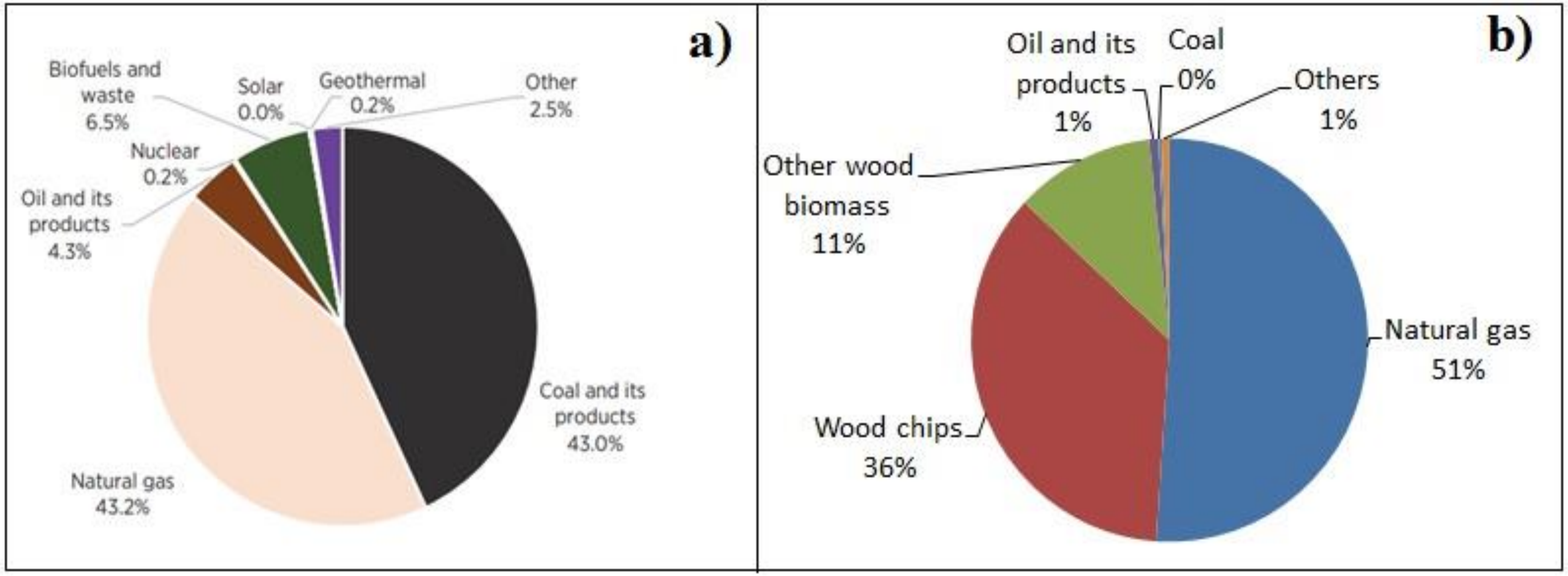
RTU VASSI

Problem definition

Globally nearly 80% of produced energy comes from fossil fuels.

In Latvia 53% of heat in DH systems comes from non-renewable energy sources such as natural gas. Use of wood biomass also creates particulate matter emissions from burning and GHG from transportation.



Breakdown of fuels used in DH systems: a) worldwide (2015 data) ; b) Latvia (2015 data) info.Eurostat

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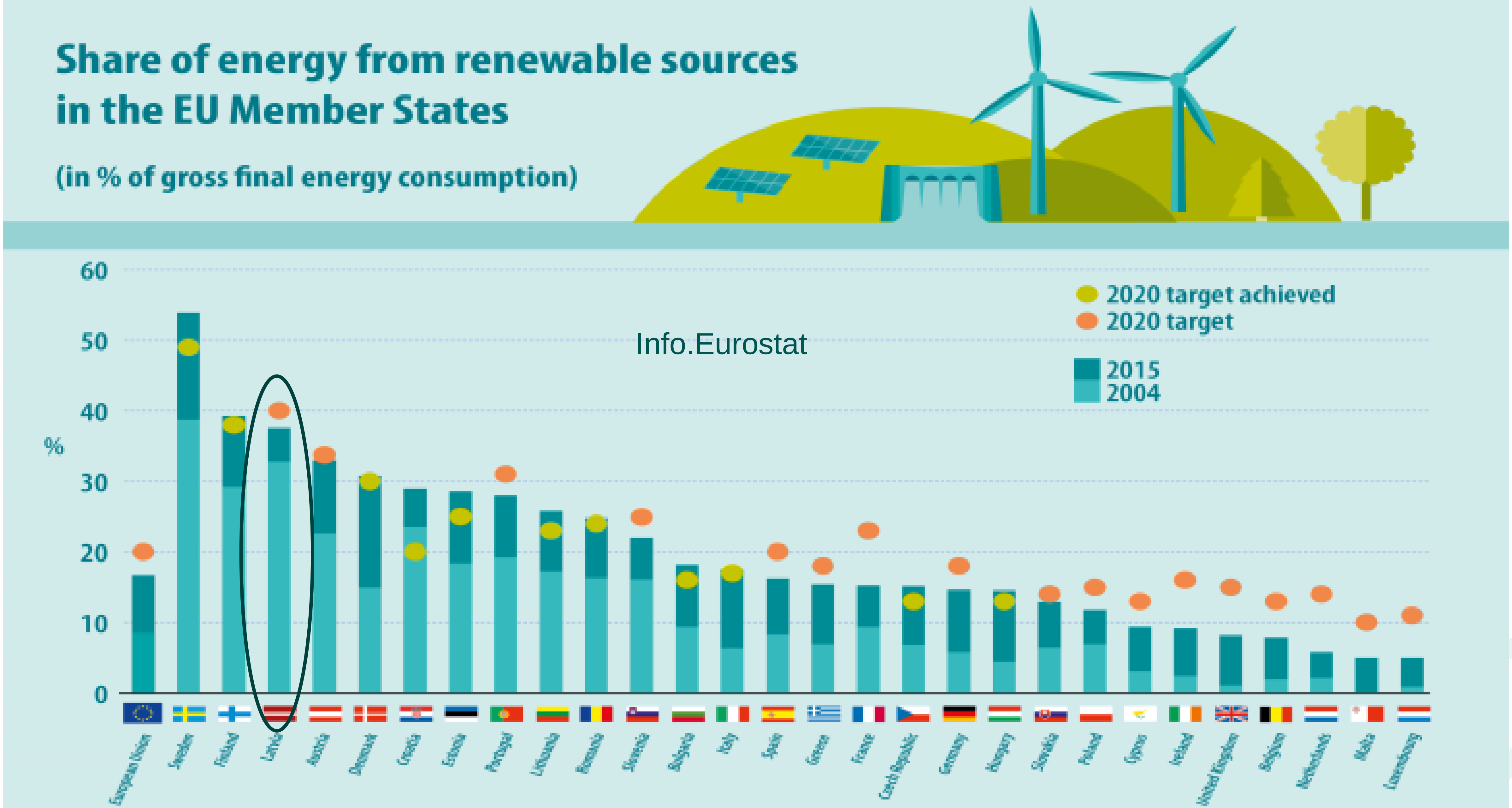
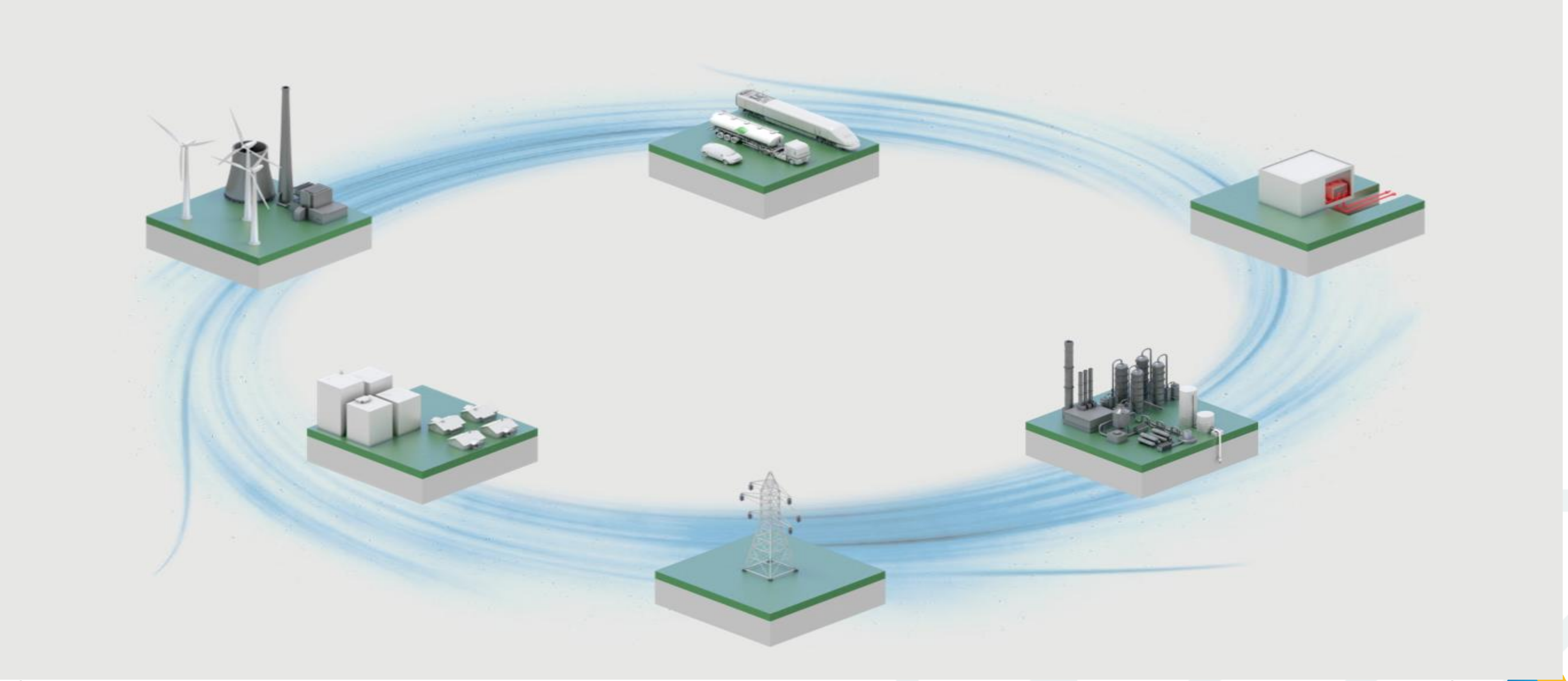

Share of energy from renewable sources
in the EU Member States
(in % of gross final energy consumption)
Info.Eurostat
2020 target achieved
2020 target
2015
2004
%
60
50
40
30
20
10
0
European Union
Sweden
Finland
Latvia
Austria
Denmark
Croatia
Estonia
Portugal
Lithuania
Romania
Slovenia
Bulgaria
Italy
Spain
Greece
France
Czech Republic
Germany
Hungary
Slovakia
Poland
Cyprus
Ireland
United Kingdom
Belgium
Netherlands
Malta
Luxembourg

Flexible energy supply/demand info: NER project Flex4RES



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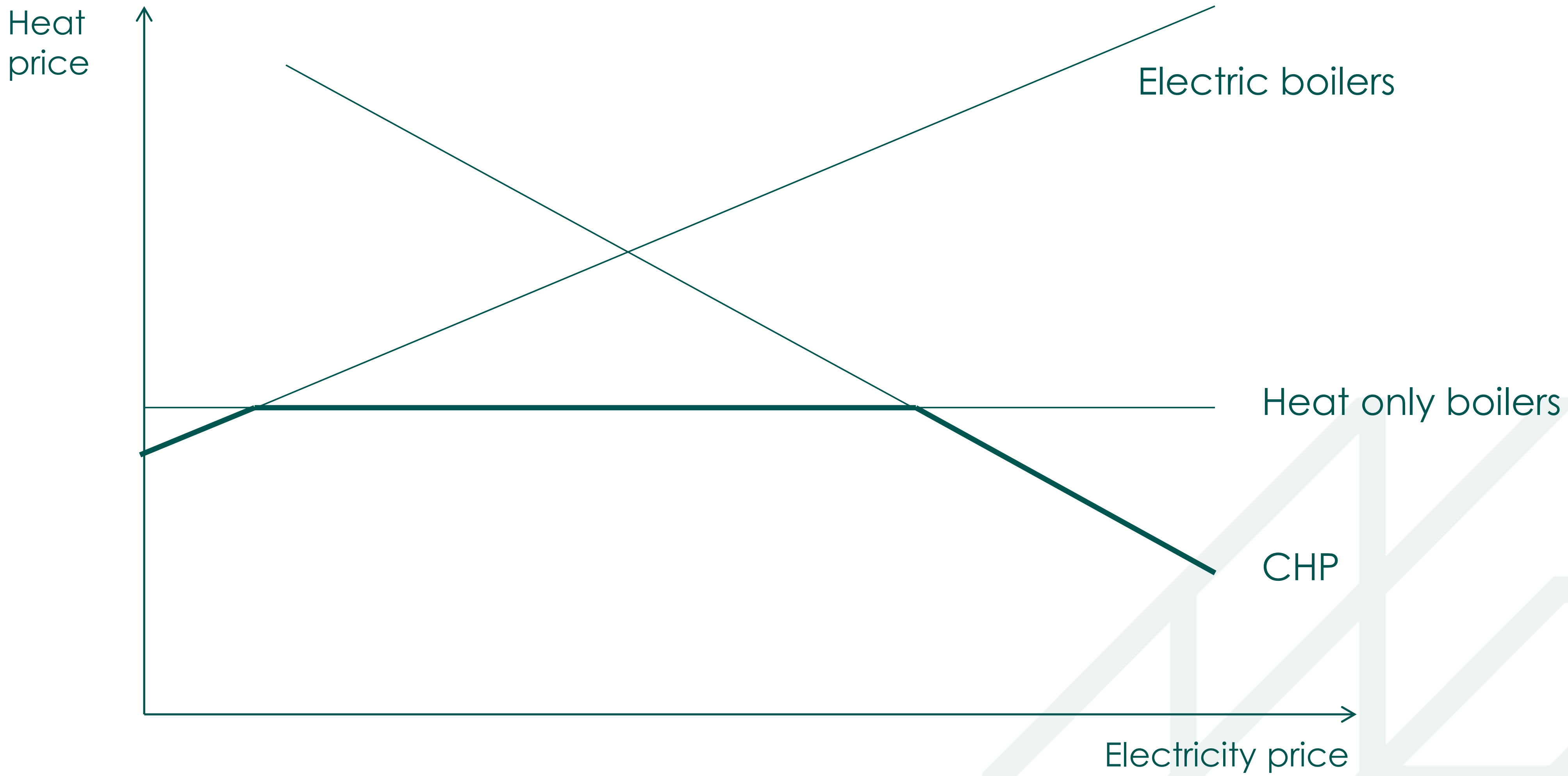
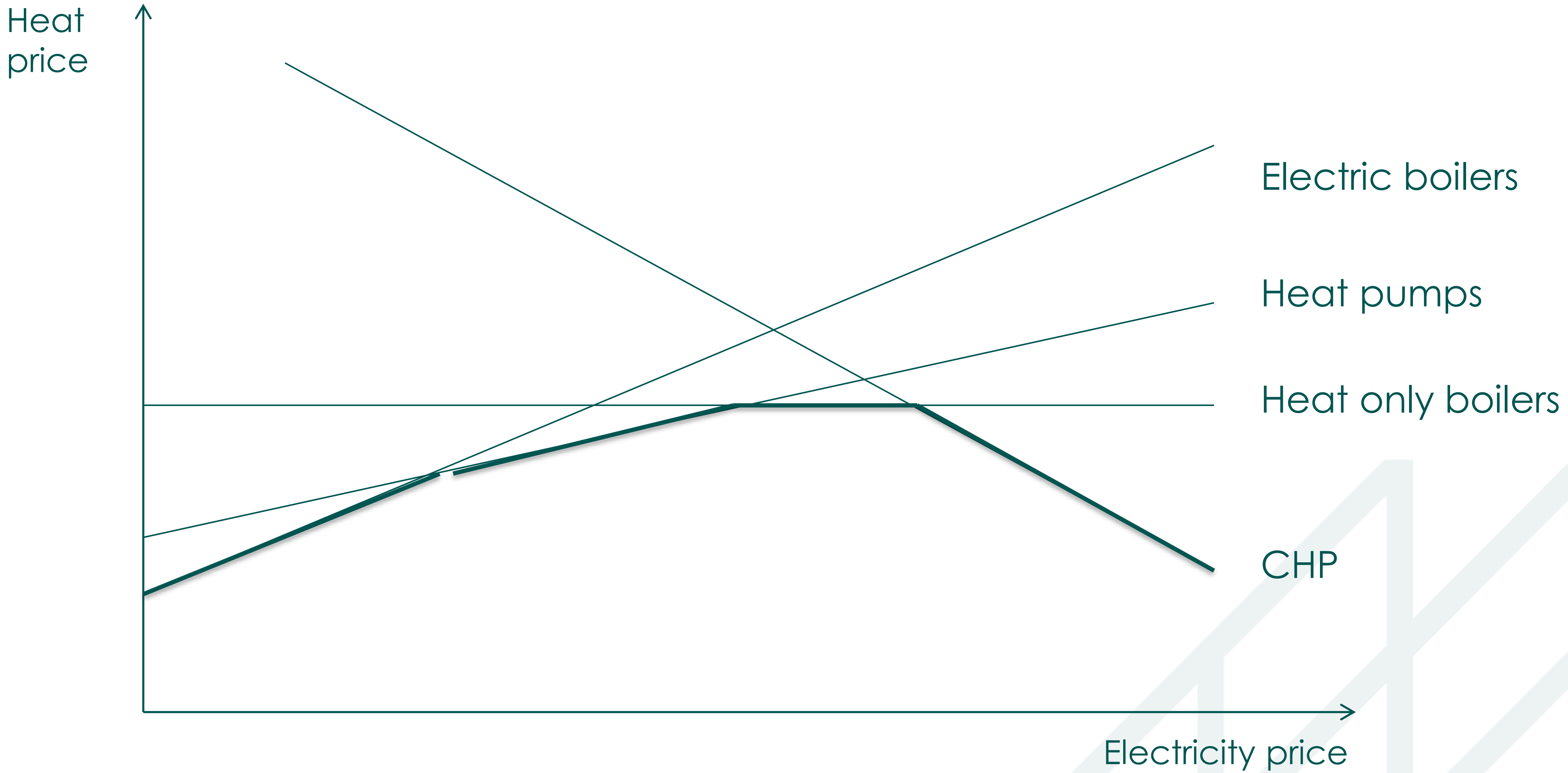
Choice of heat supply - at different electricity prices info: NER project Flex4RES

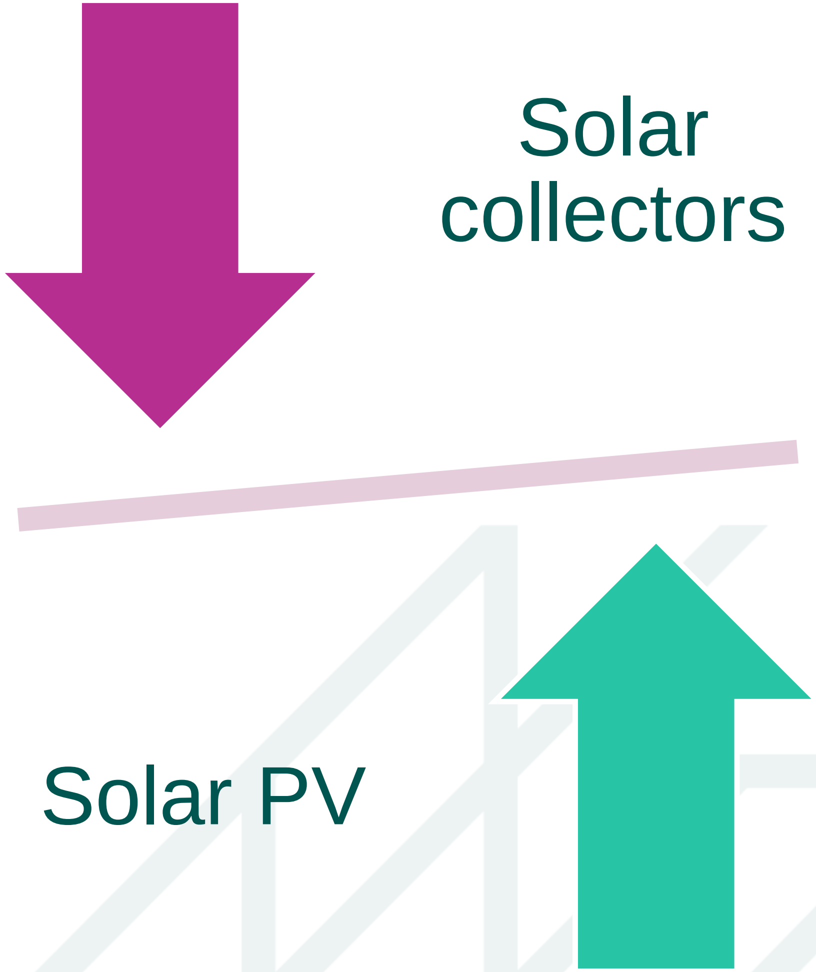


District heating-electricity interface info: NER project Flex4RES



Research Goal

- To determine whether the integration of Solar PV panels into DH systems is economically feasible, by taking to account the significant decrease of Solar PV system prices and the development of DH systems.



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Main tasks

- Determine the best PV integration model for particular DH Company;
- Evaluate existing experience and methodology for solar energy integration in DH systems
- Create a systemdynamics model that allow analyzing the long-term economic benefits of using solar PVs for a single heating company
- Analyse the flexibility of system for transferig power to heat when it is economicaly reosenable

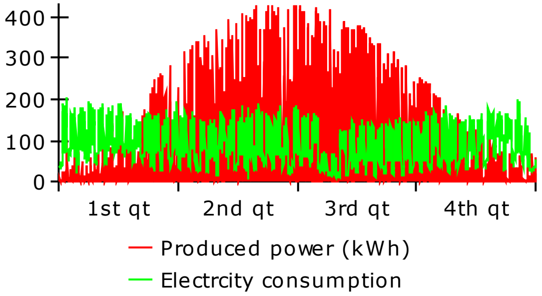
Solar DH system elements

PV panel system

Power

Self-consumption

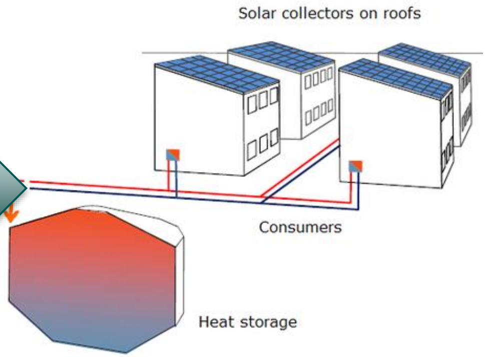
Power



Overproduction

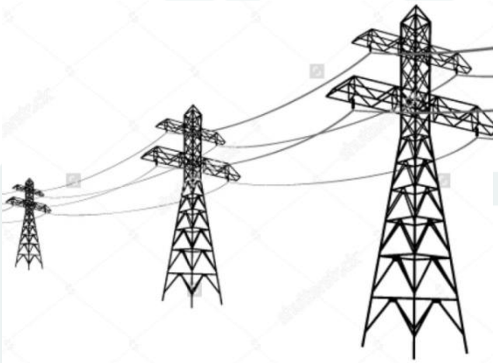
Heat pump

Heat



Power

Power



Back to grid

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Methodology

Taking into account the complexity of DH system and all the feedback loops, a SD model is used in this study. The SD theory is based on the complex system that analyzes behavior, which changes over the time.

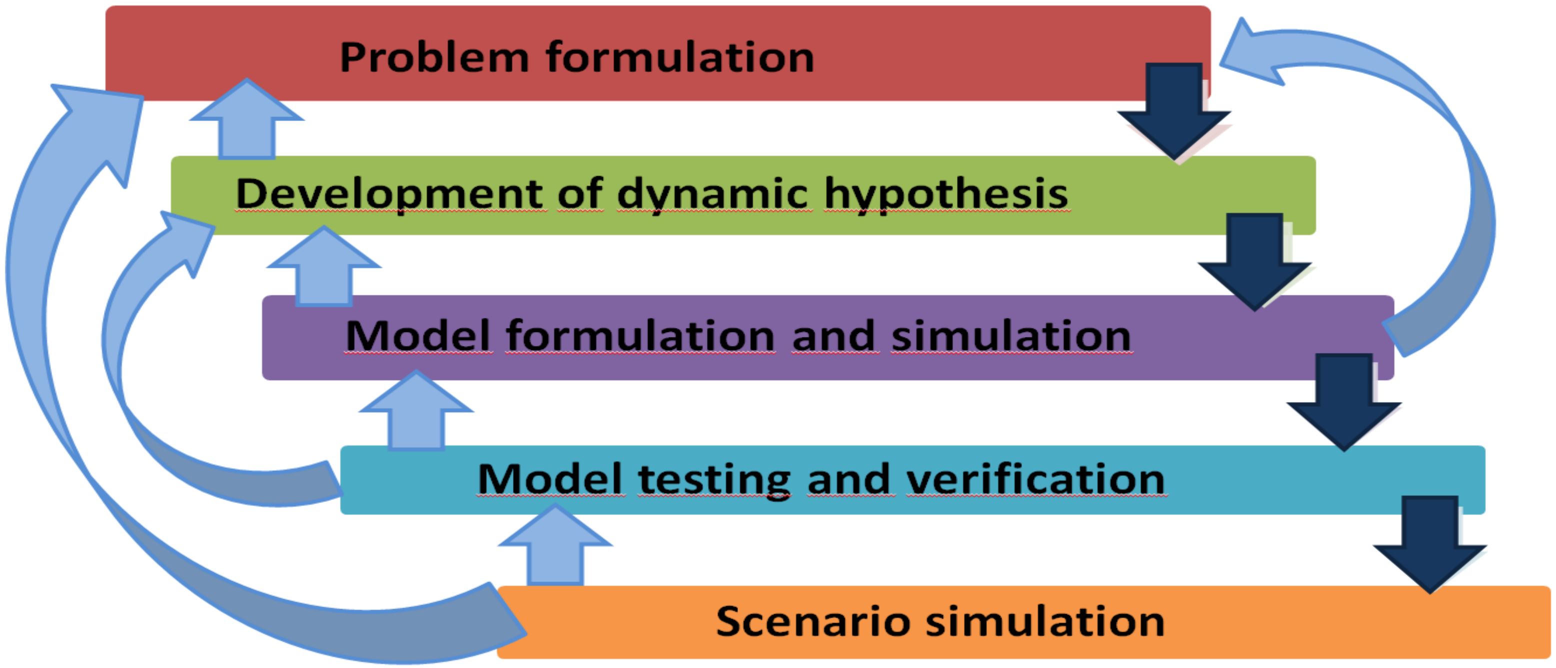

Fig.3. Algorithm for model development and validation

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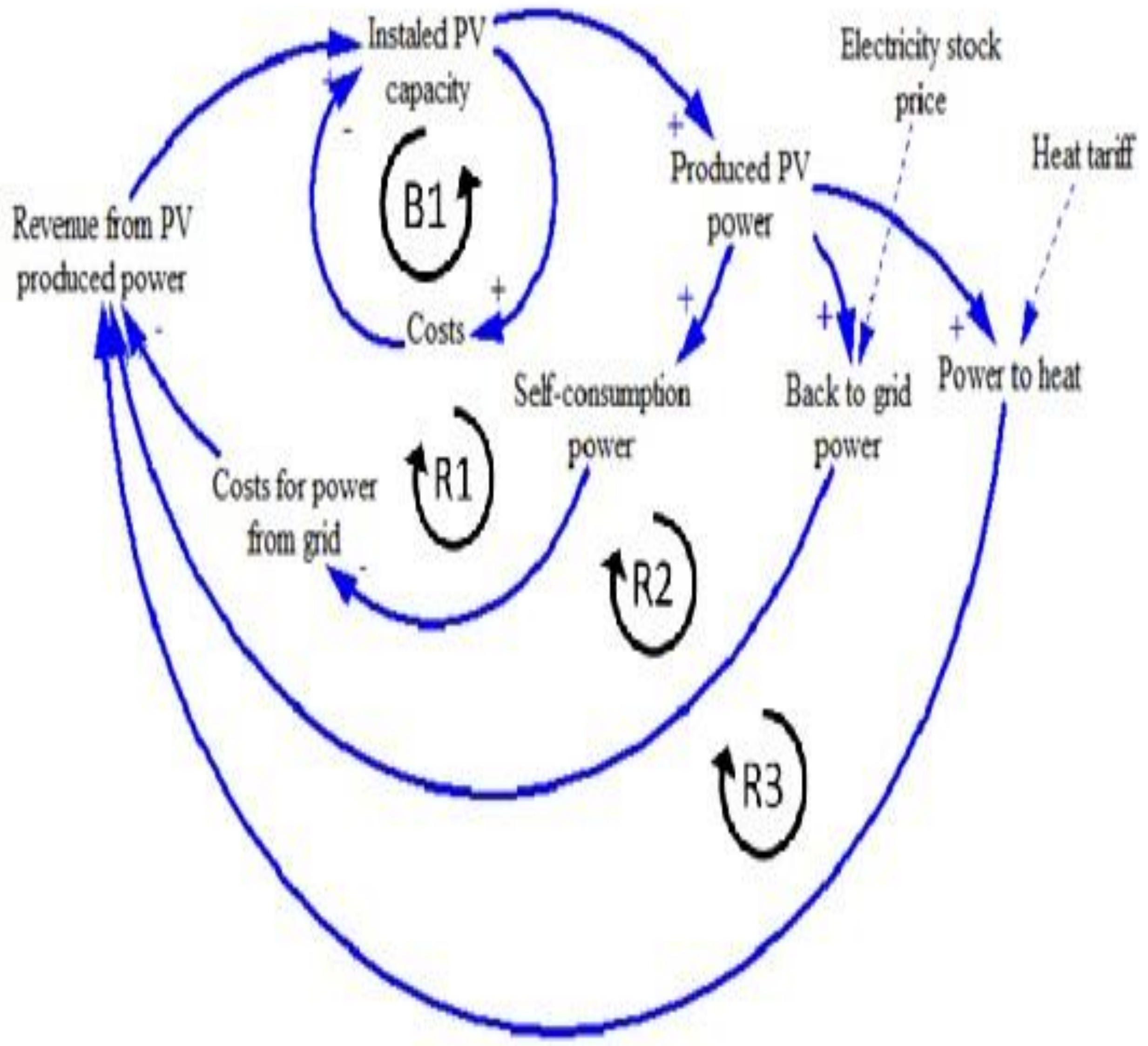
Methodology

- System dynamics (SD) is a method for studying the dynamic development of complex systems such as DH system.
- System dynamics theory is based on the study of the relationship between system behavior and the underlying structure of the system.



Structure of the model

- Installed PV area sub-model
- Produced and consumed power sub-model
- Overproduction use pattern sub-model
- PV system revenue sub-model
- Total PV system costs sub-model
- Heat pump capacity sub-model
- Indicated HP heat tariff sub-model
- CO_2 emissions calculation sub-model

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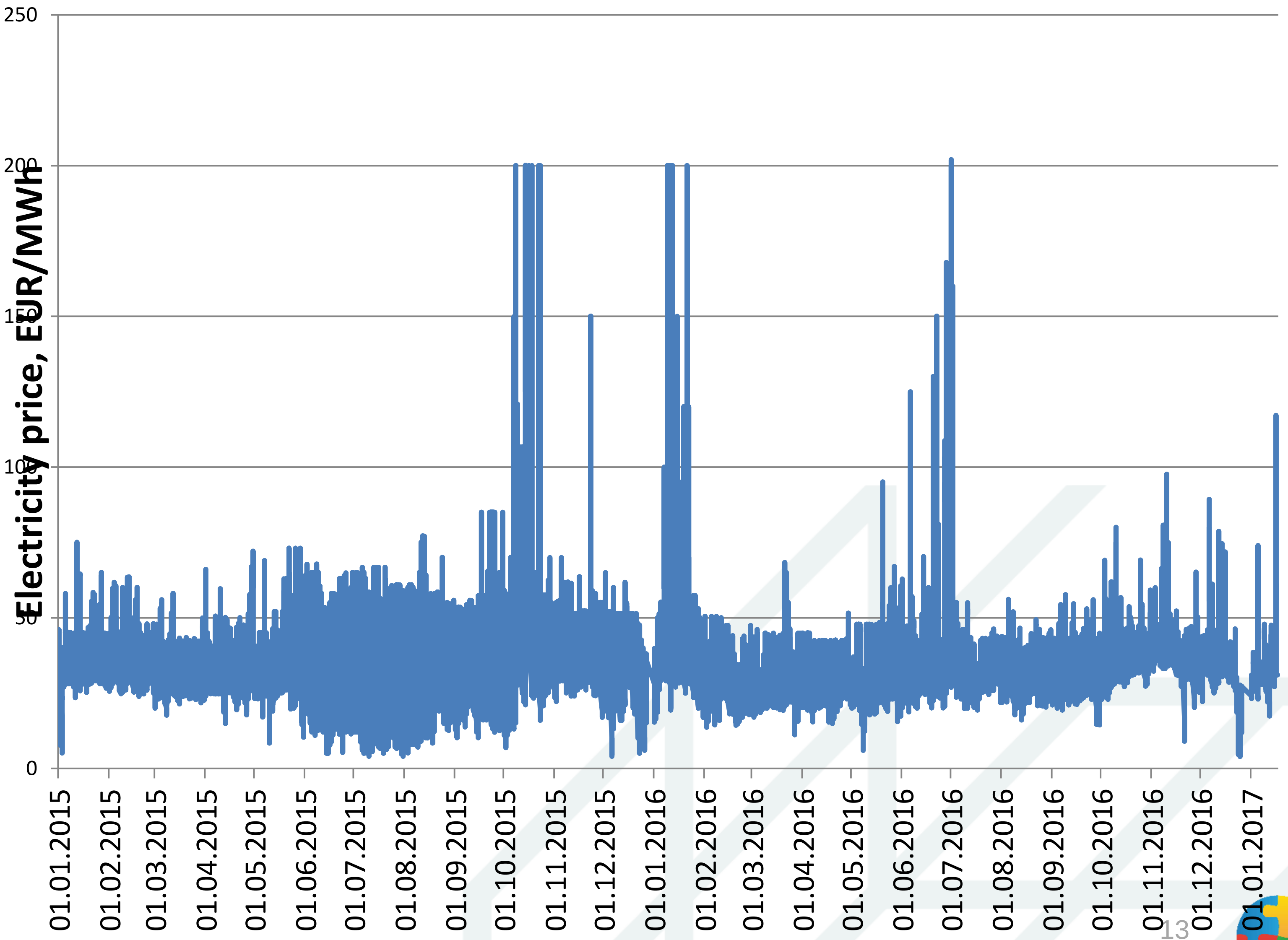
Dynamic input data for model

- PV panel price;
- Electricity and heat consumption from heat power company;
- Solar radiation data;
- Electricity price from Nordpool spot;
- Full payment for electricity;
- Heat pump efficiency;



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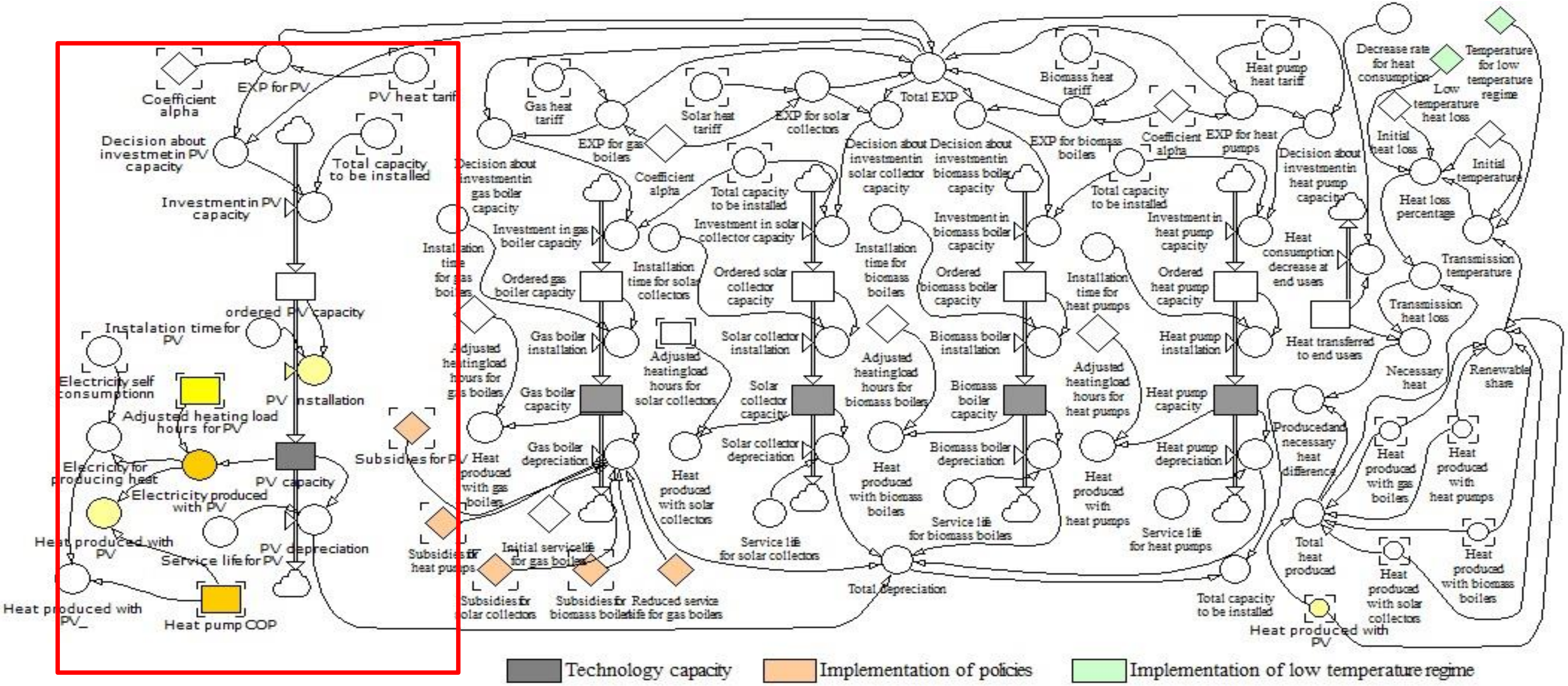
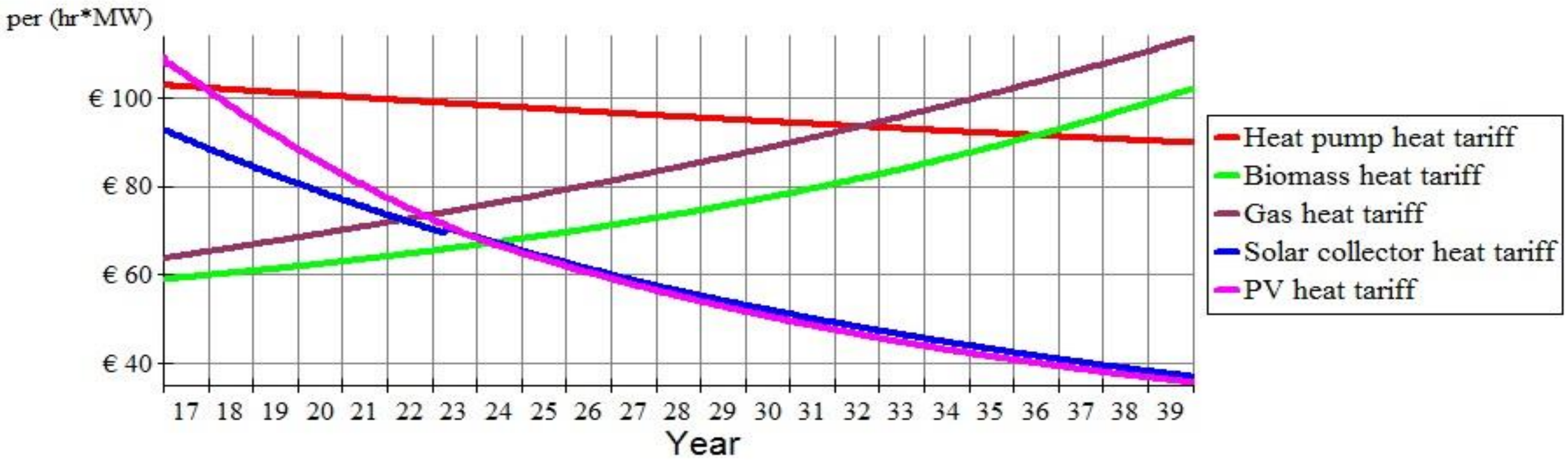
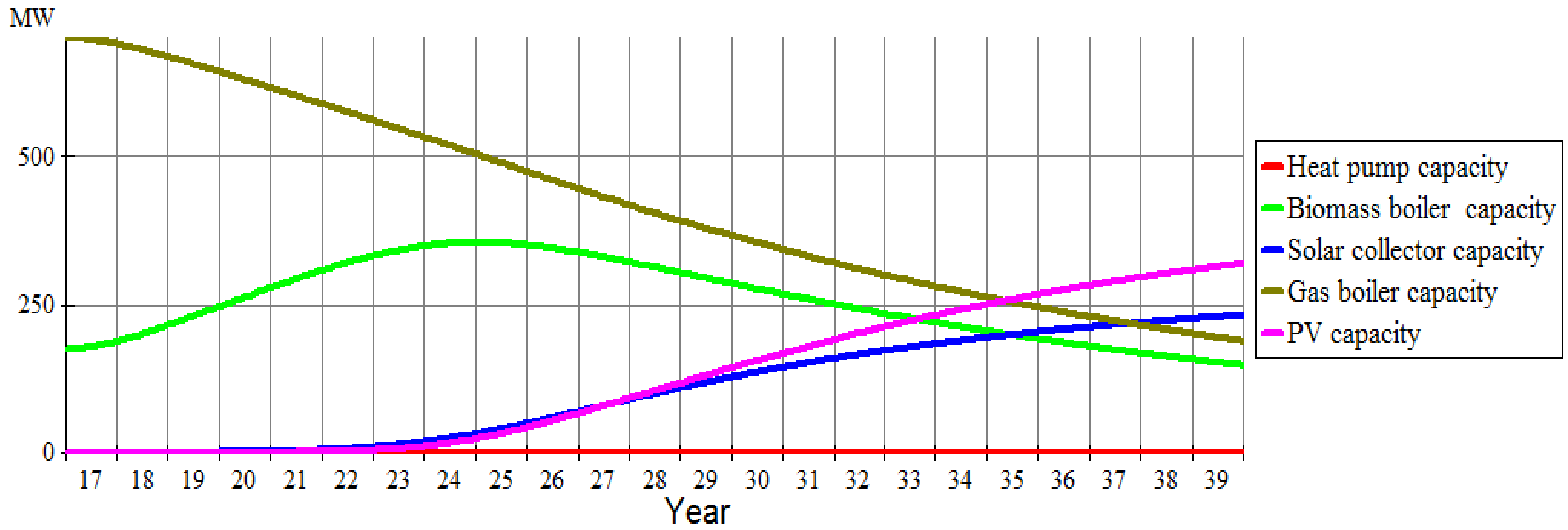
SD model for PV integration in DH system in annual bases



Technology capacity replacement model in DH system



Modeled Heat tariff changes over years (2017–2040)



Modeled Technology capacity changes over the years (2017–2040)

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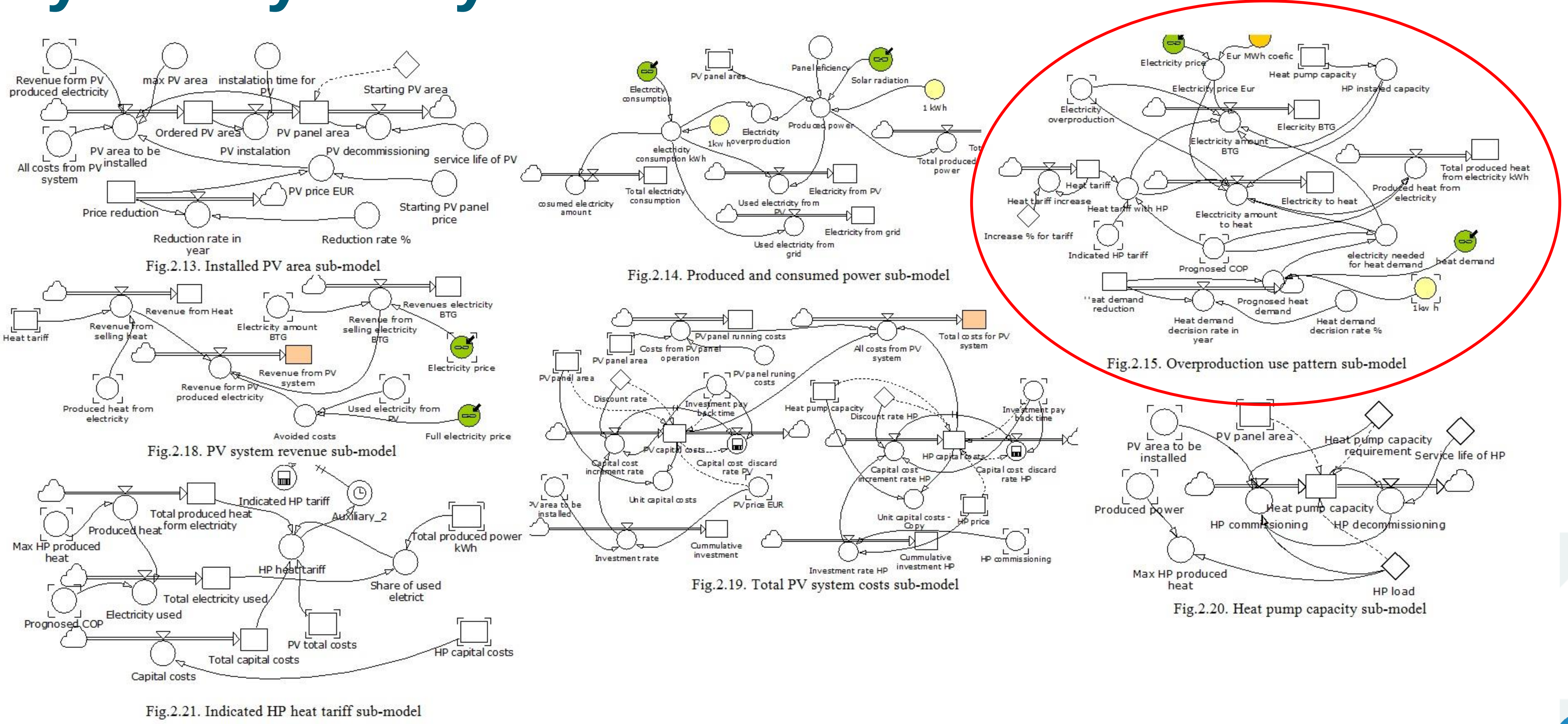
SD model for PV integration in DH System by hourly analyses



Hourly analysis DH system model

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Model validation

- **The model structure verification test**- the model structure where compared with other DH models that have been made before.
- **Parameter verification test**- the parameters are in line with the real system as the model is developed by using acquiring scientific and market based data
- **Extreme conditions test-** by radically changing main input data, the model behavior is normal and the balancing loops are limiting the unnatural results;
- **Uniformity test** - all the used units where compared to match the input value and also coincide with different parts of the model.
- **Behavioral sensitivity test-** analyses the values that were marked by significant differences in various sources (PV and HP technology installation costs)

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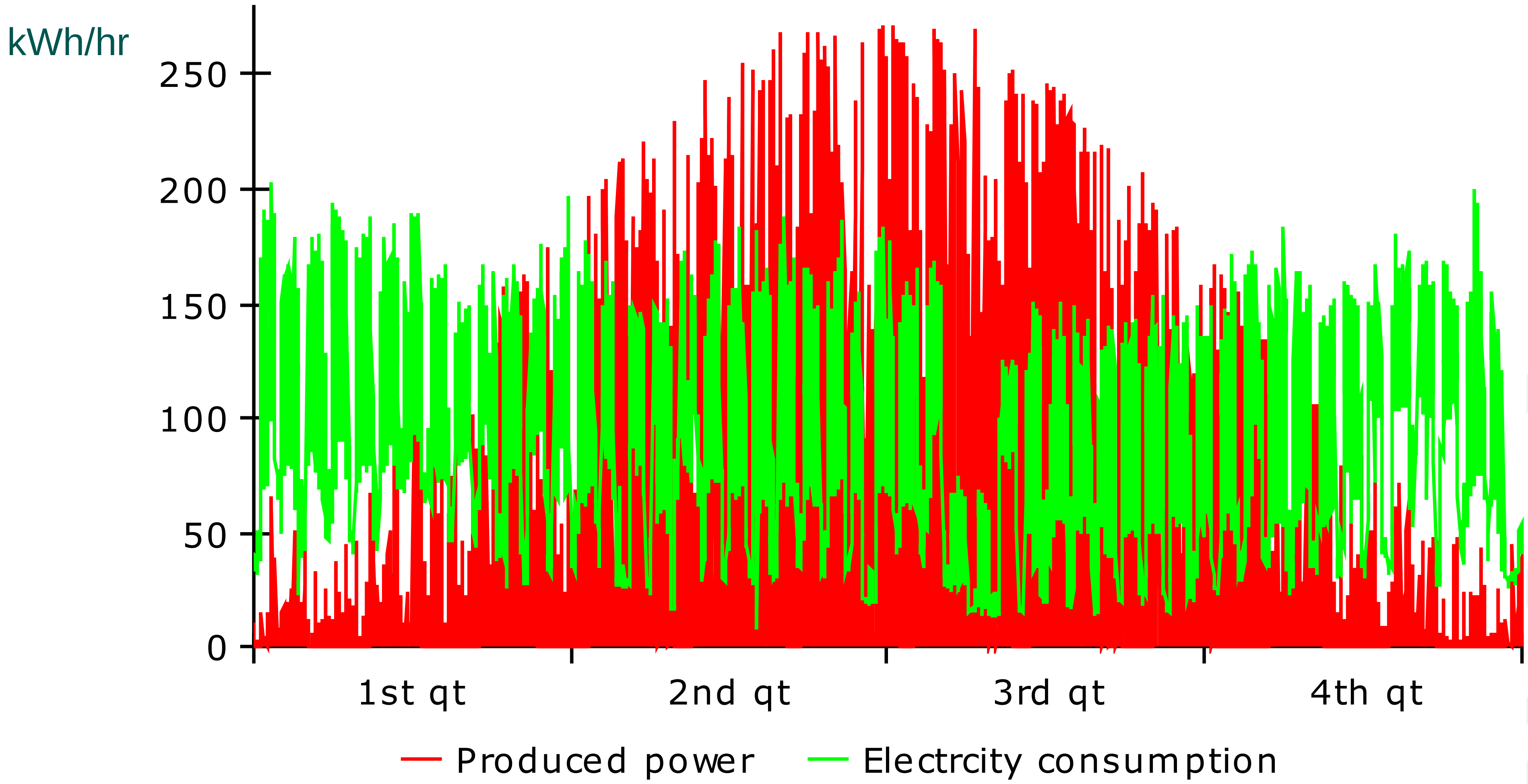
Results (1)

- Self consumption coverage



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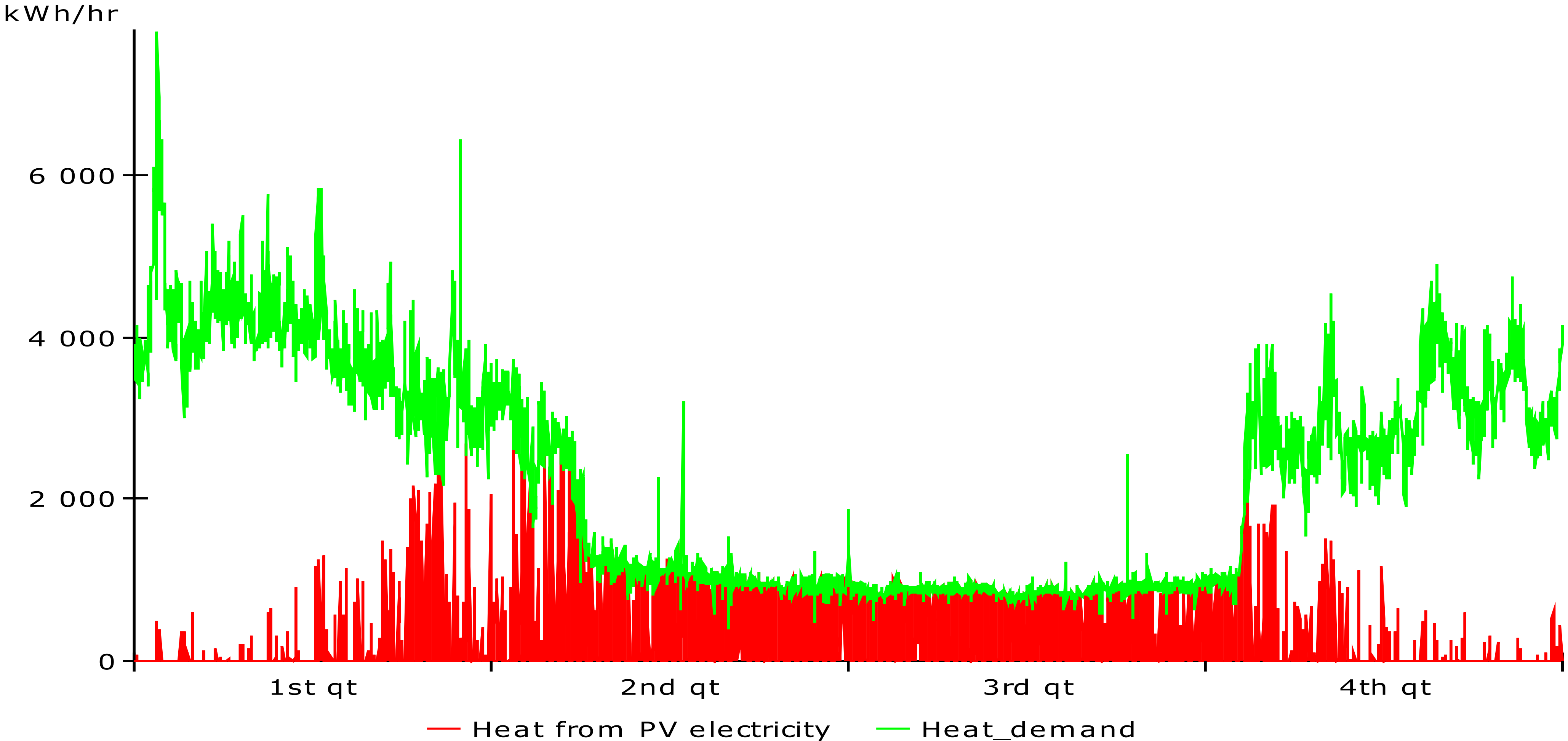
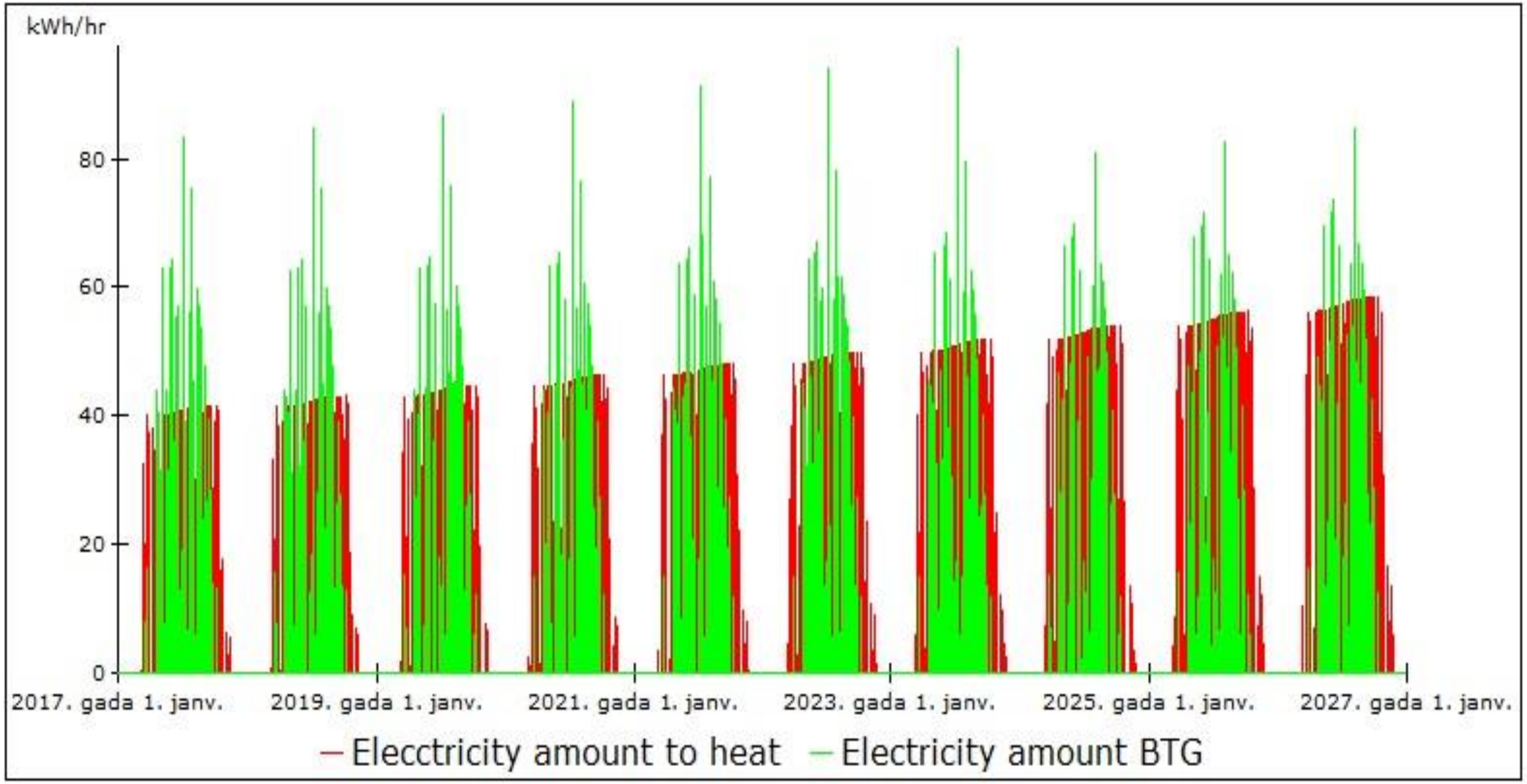
Results (2)

▪ Heat consumption coverage from solar power-to heat



Results (3)

- Breakdown of overproduced PV power (BTG- back to grid) Year 2017-2027



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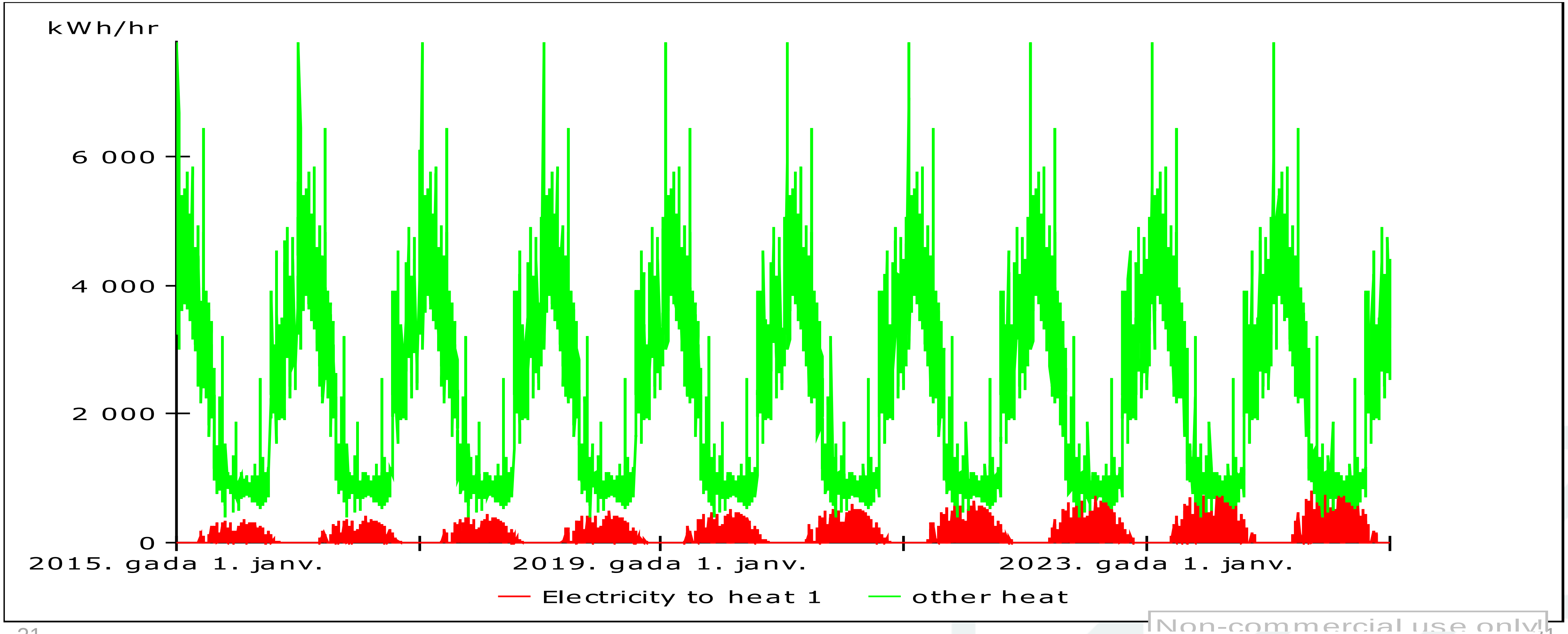
Results (4)

- Breakdown of PV power to heat Year 2017-2027



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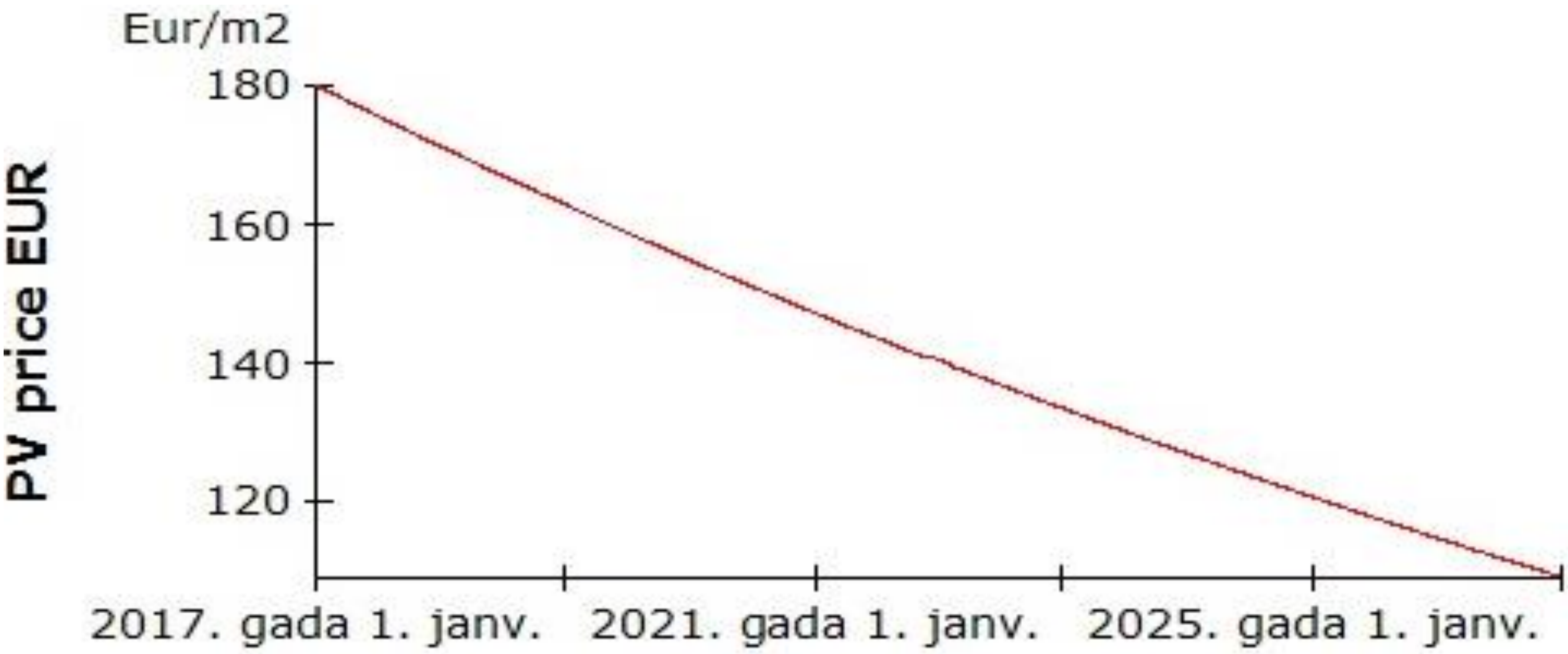
Results for simulation (2017 – 2027)



PV system installation price change

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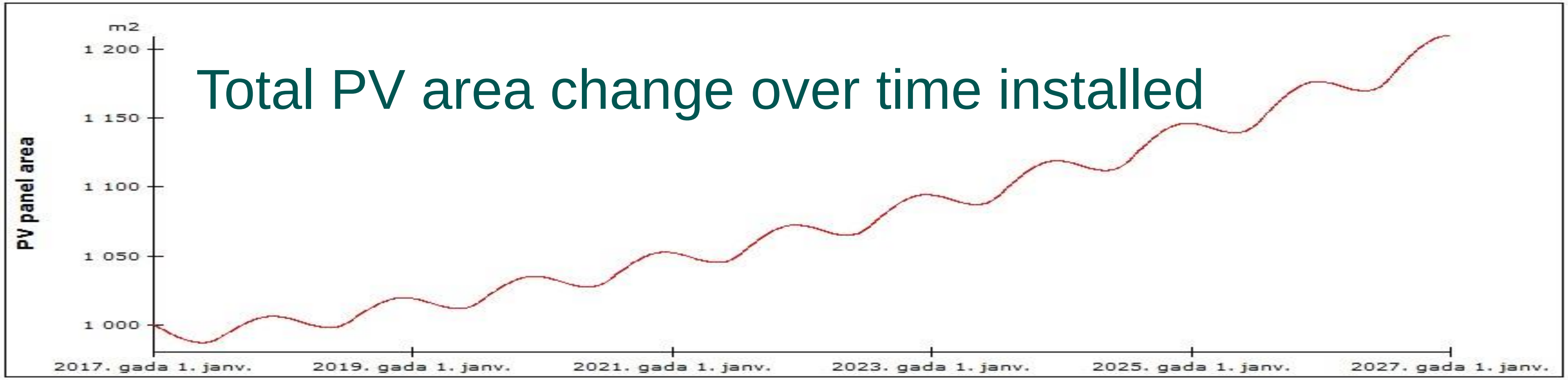
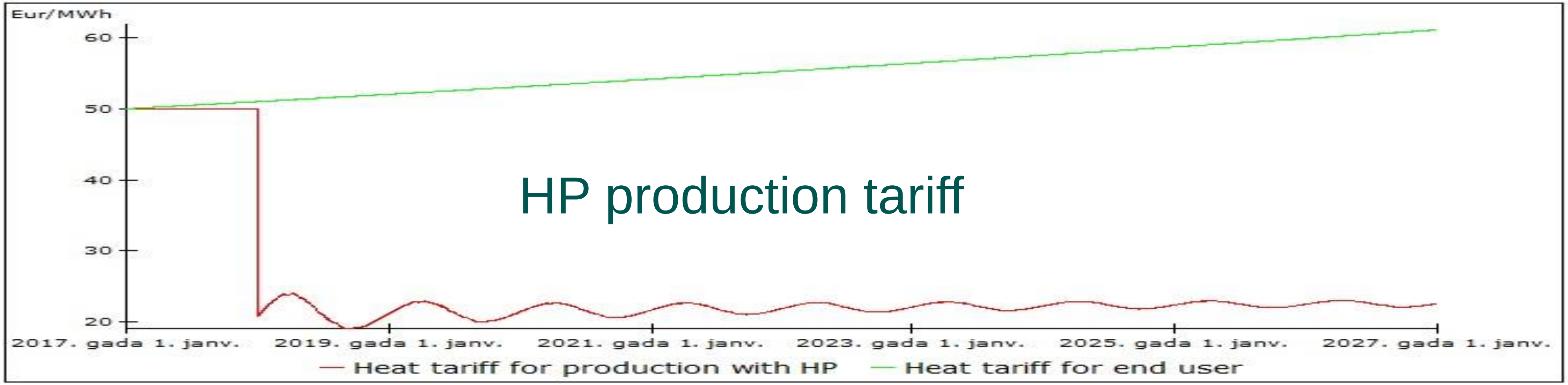
Results for simulation (2017 – 2027)





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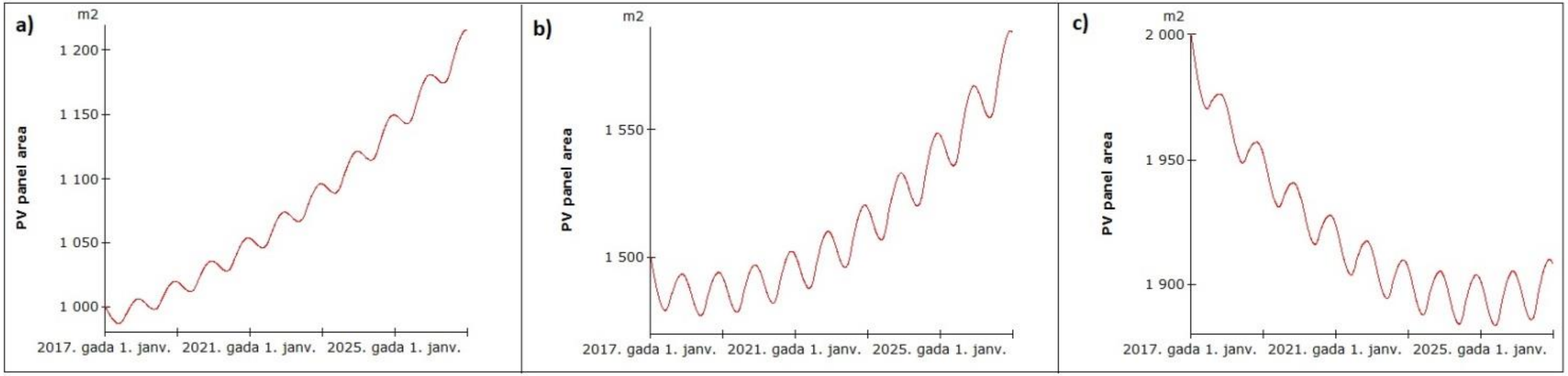
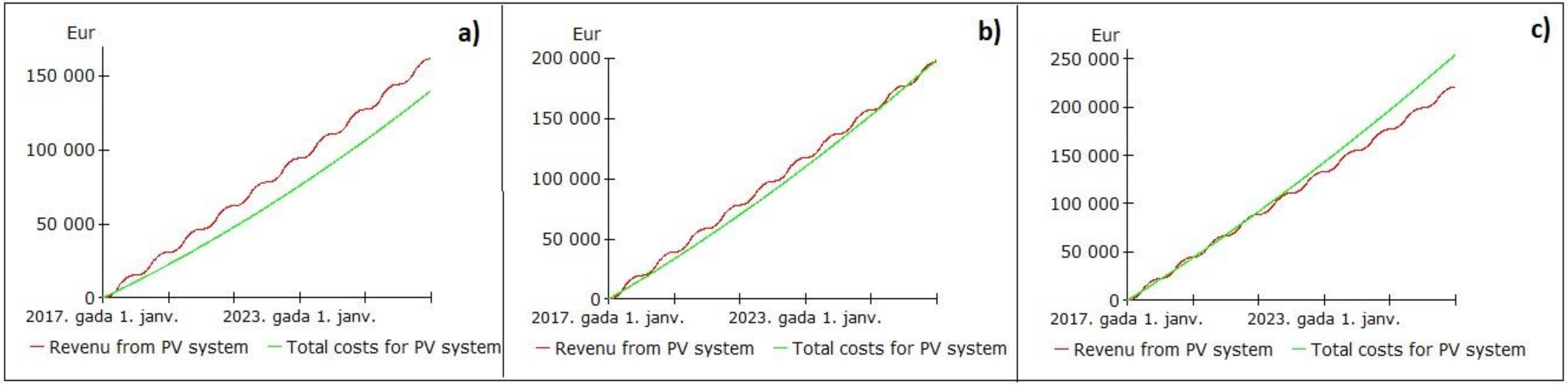
Comparison and analysis of different scenarios

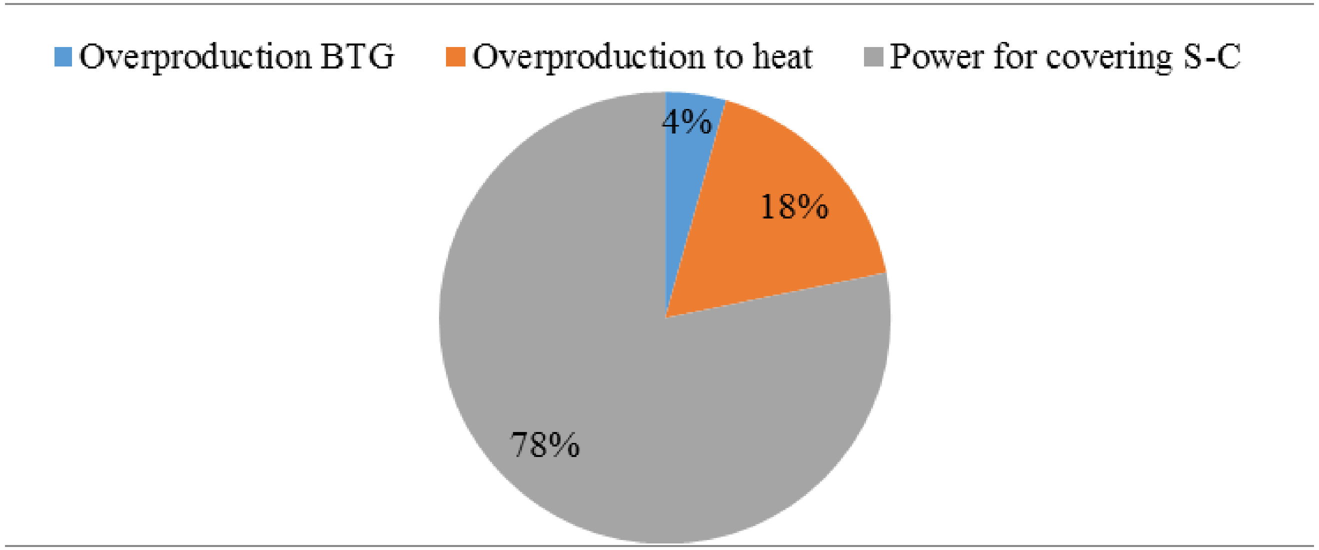


The total PV area changes in different starting area scenarios (a – 1000 m^2; b - 1500 m^2; c - 2000 m^2)

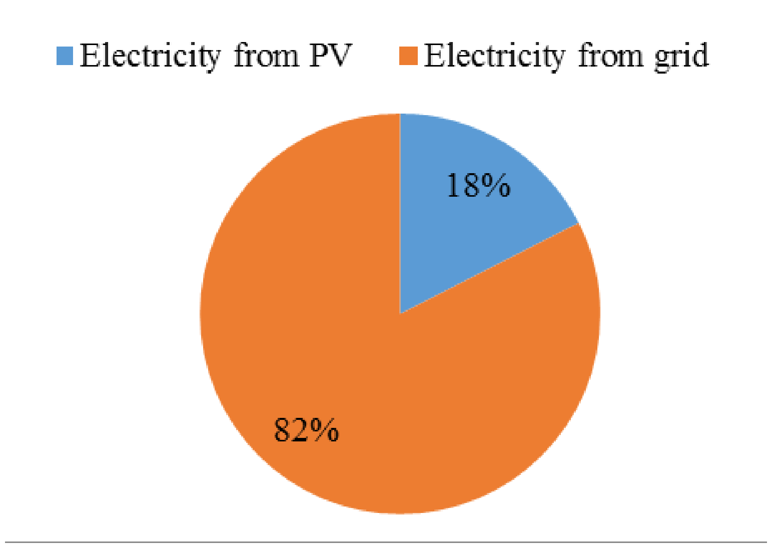


Revenue and costs for different PV system scenarios (a – 1000 m^2; b – 1500 m^2; c – 2000 m^2)

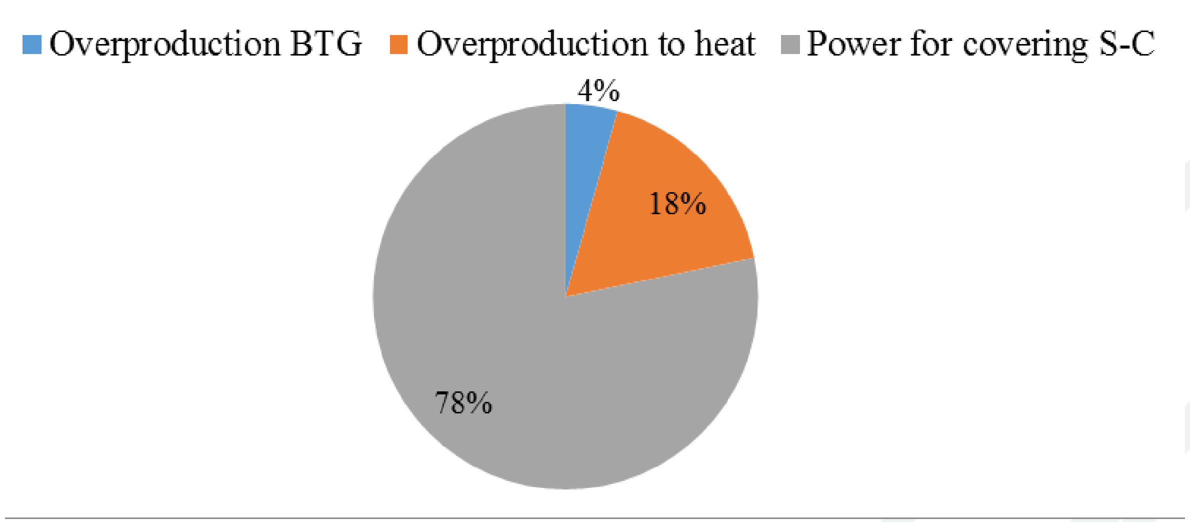
Results



Overproduced PV power distribution



Electricity self-consumption distribution



Saved CO_2 emission distribution by place of origin

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Conclusions (1)

1. The hypothesis that integrating PV technology into the DH system is competitive and economically feasible has been tested by system dynamics model. Model confirmed that based on forecasted PV technology price reduction, this technology can be solution for sustainable development of DH system.
2. The results showed that it is profitable to install larger PV area than needed for summer electricity consumption. The baseline system increased its total area for 18% in 10 years' time, only use of profit from produced power.
3. Best integration model for heat company is when PV system can produce electricity to cover about 40 % of self-consumption

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Conclusions (2)

4. The power-to-heat concept can increase the flexibility of solar DH system. For integrating the larger PV starting are, the overproduced power can be transferred BTG or used for heat production via HP.
5. In average about 80% of overproduced power are converted into heat and 20% are sent BTG. This distribution depends on installed HP capacity and both electricity and HP installation price.
6. Model can help to determine the optimal PV integration area for particular DH system. To use this model for evaluating the PV technology integration potential the hourly data needs to be provided from the company.

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Acknowledgement

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