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Solar power or solar heat: What will upraise the district heating?

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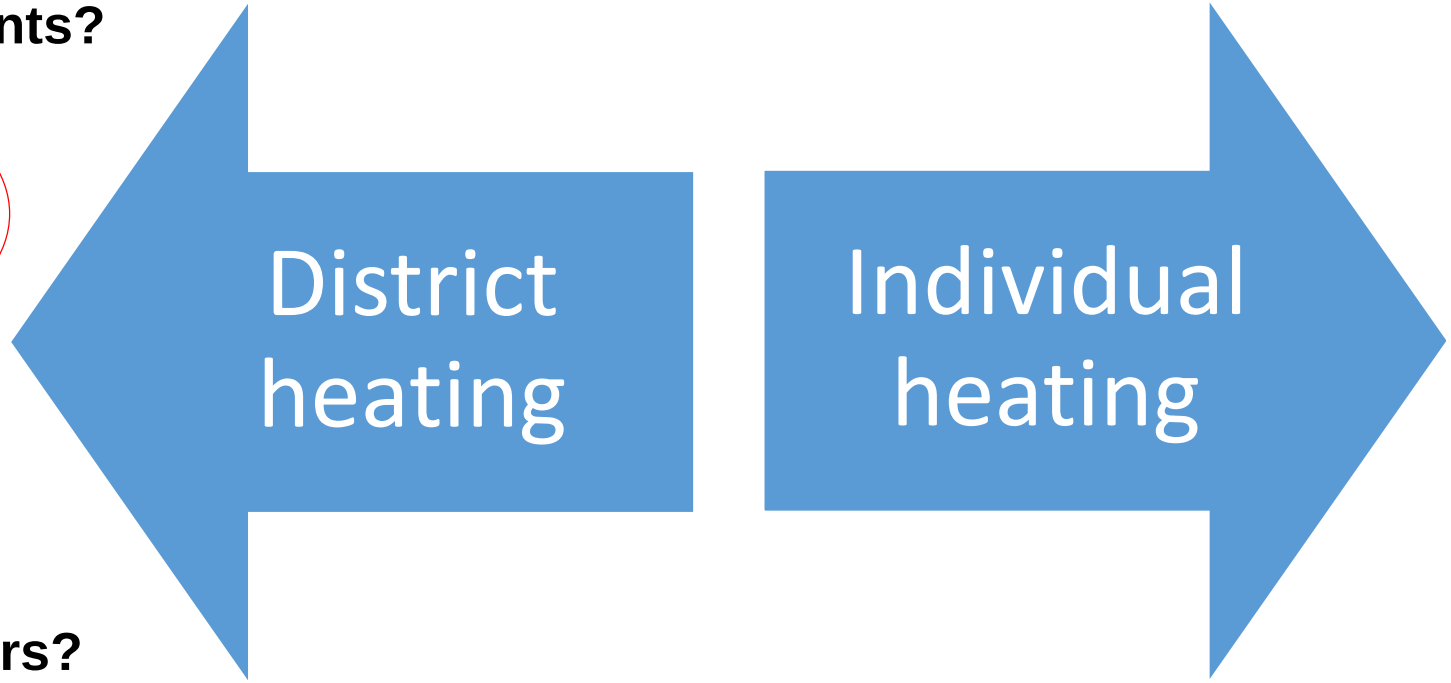
Problem definition

- Energy balance towards 4th DH systems brings challange for flexibility of renewable electricity resources:
  - ~~Fossil fuel~~
  - Biomass
  - Gheothermal energy
  - Solar
    - Collectors
    - PV

Future of district heating



Virtual heat plants?

Solar collectors?

PV panels?

Waste heat?

CHP?

Biomass boilers?

Heat pump?

???

Heat pumps?

Solar collectors?

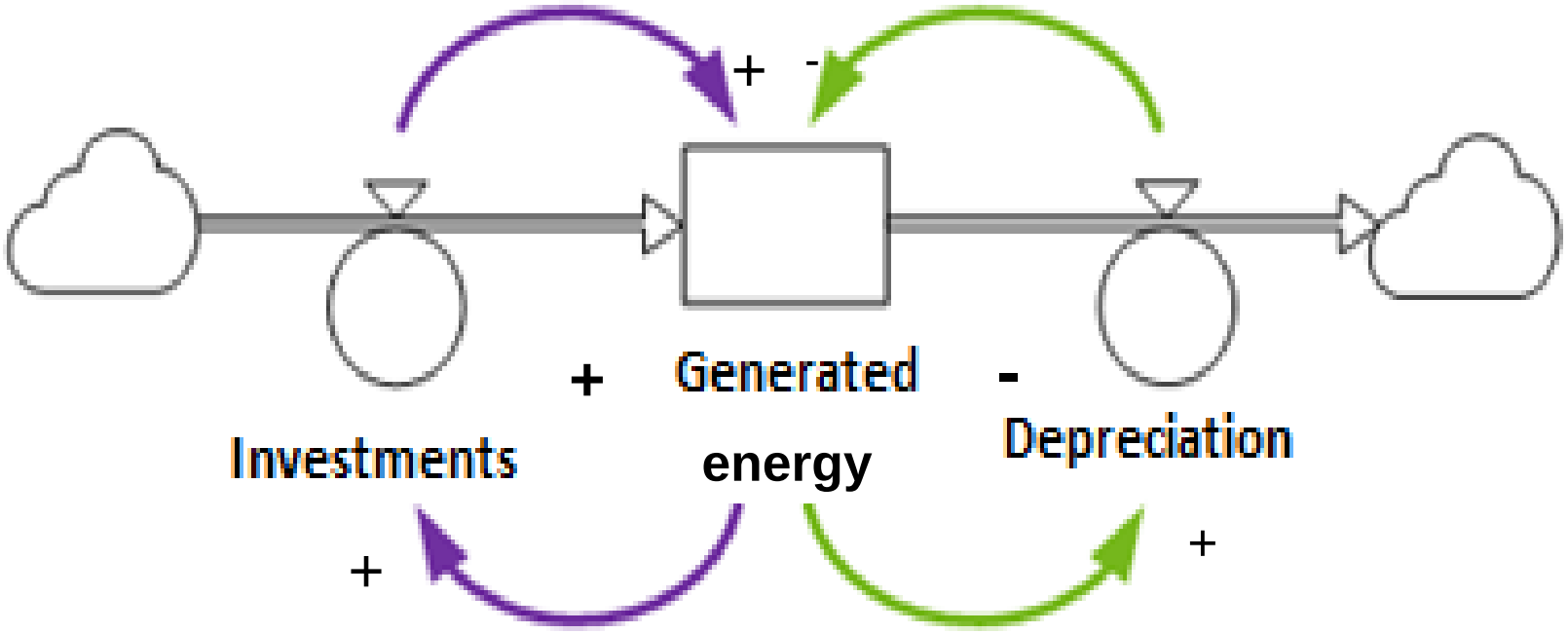
PV panels?

Biomass boilers?

Zero energy buildings ?

???

Relationship between the generated energy, and investment and depreciation flows



Future of DH system – solar energy

Research Goal

- To evaluate different solar thermal, solar power and solar combisystem configurations for district heating (DH) application by taking into account:
  - Solar power to heat (P2H) concept;
  - DH temperature lowering potential;
  - Heat and power price changes;

Hypothesis

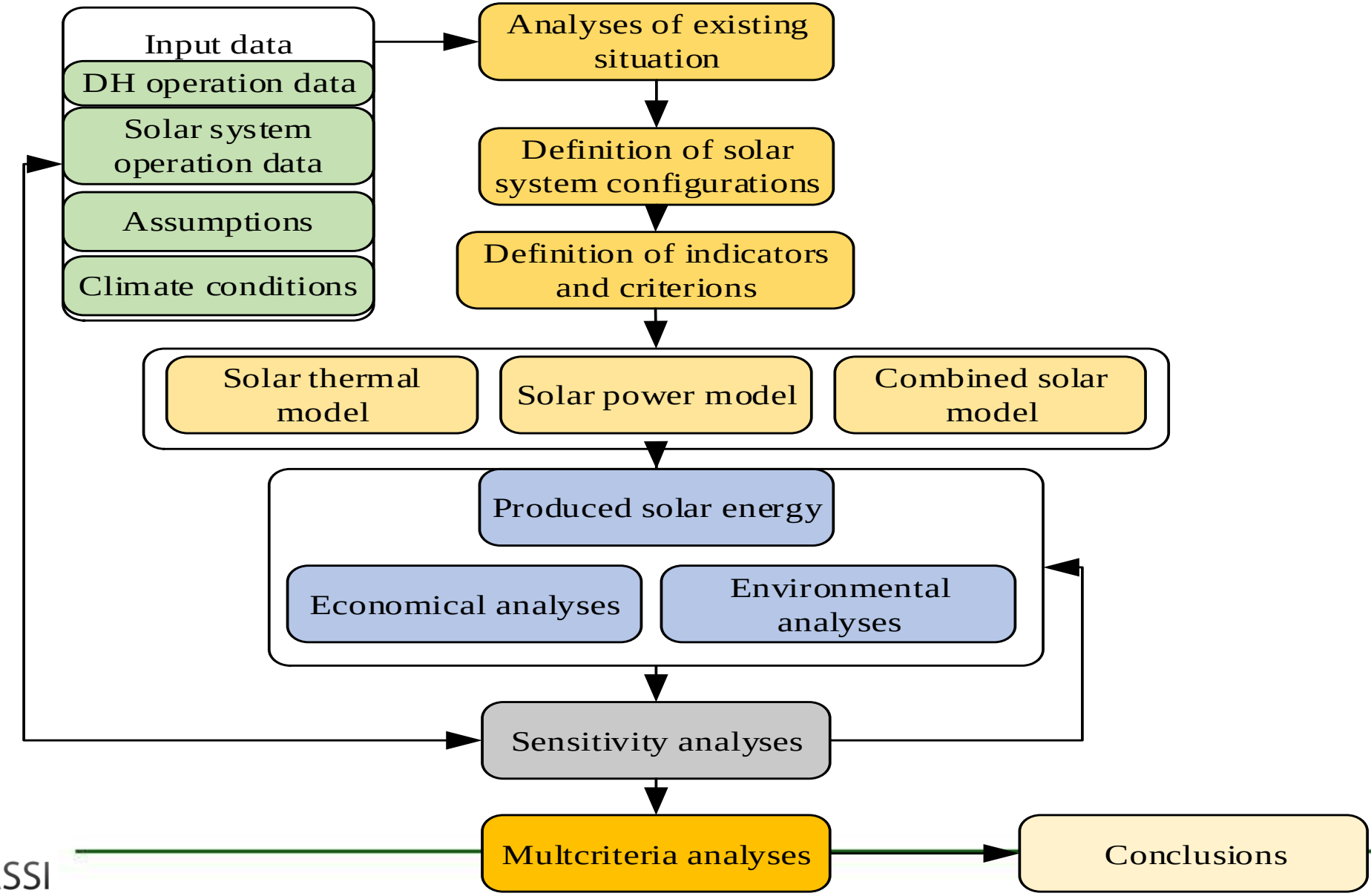
- Investments in DH systems for all spectrum of solar energy installations (PV, SC and PVT) are substantial for sustainable development of DHC

Main tasks

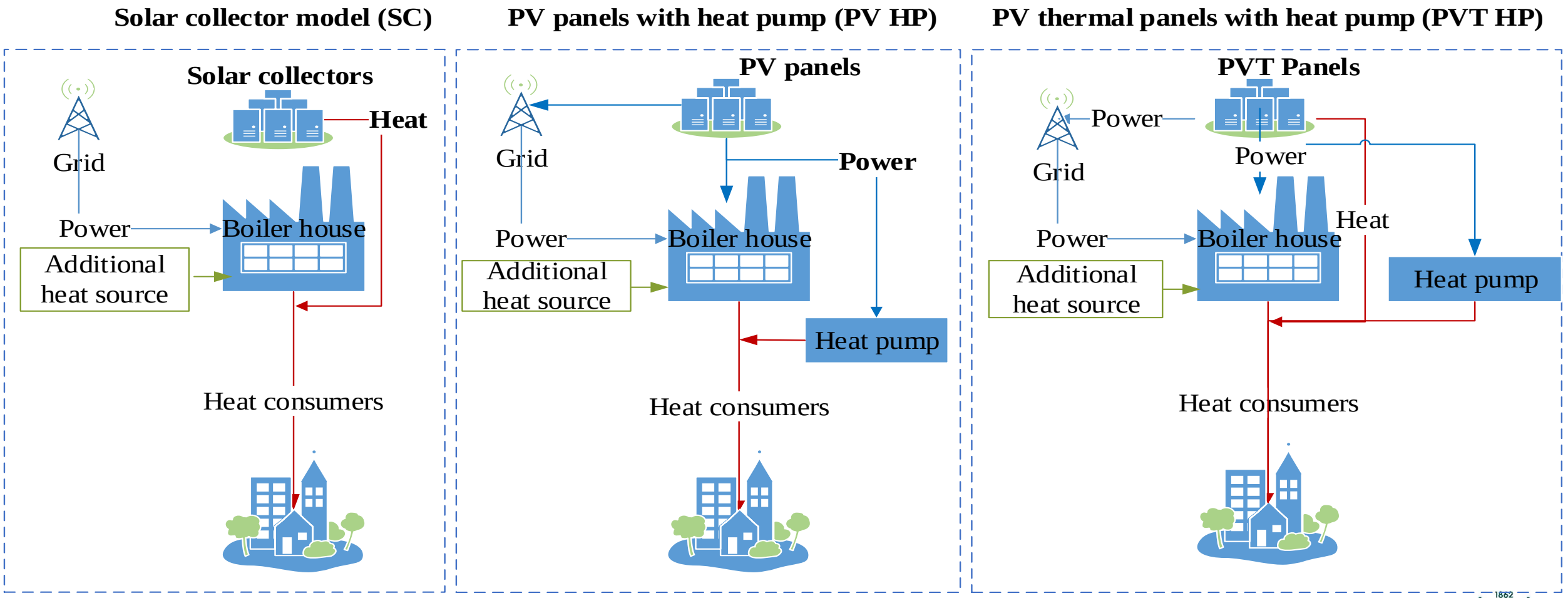
- Develop the energy balance models for different solar system configurations;
- Identify and determine main criteria describing solar system performance;
- Conduct economical and environmental analyses
- Perform sensitivity analyses for main variables and criteria
- Rank the solar system alternatives by multi-criteria analyses method

Methodology of Analysis

Research methodology



Solar DH system configurations

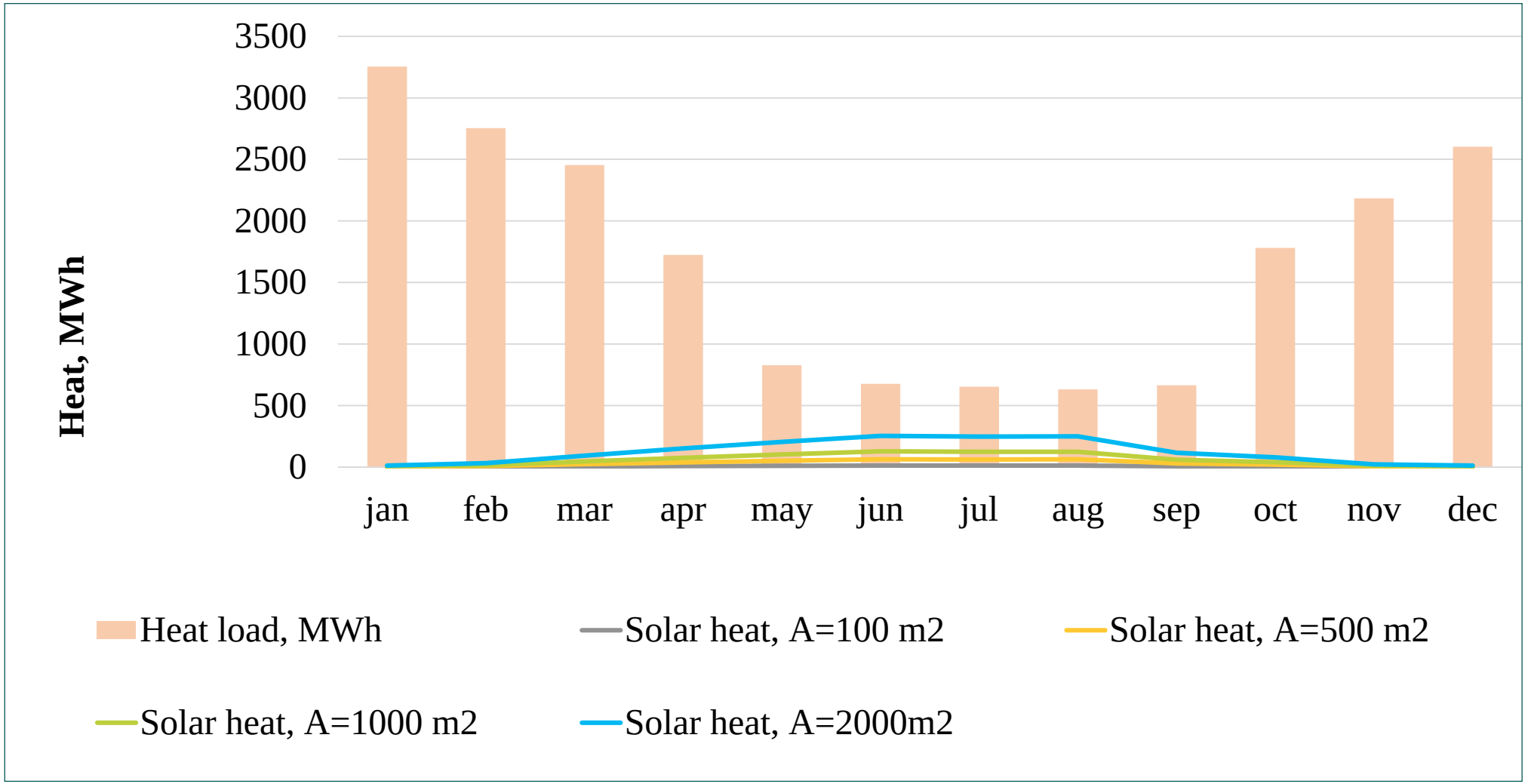


Indicators used

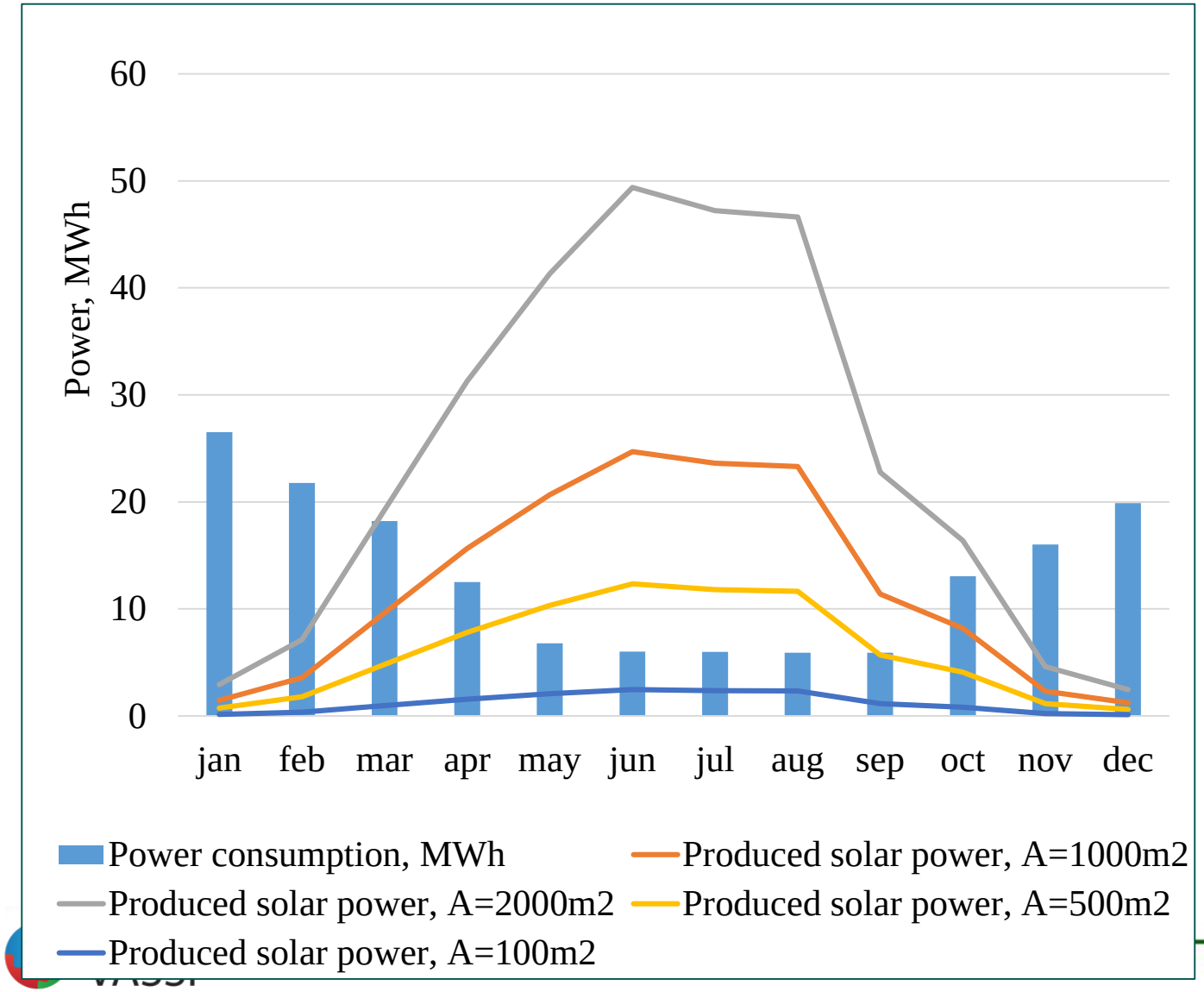
- Solar electricity and thermal energy produced and consumed per year, MWh/year
- Sold solar electricity and solar power converted to heat, MWh/year
- Solar fraction in total energy balance,%
- Produced solar exergy, MWh/year
- Specific useful exergy, kWh/EUR
- Total system costs and revenues, EUR/m^2 year
- Simple payback time (SPB), years
- Net present value (NPV), EUR/m^2
- Levelized costs of energy (LCOE), EUR / MWh
- Avoided CO_2 emissions, t_{CO2} /year
- Cost of avoided emissions, EUR/t_{CO2}

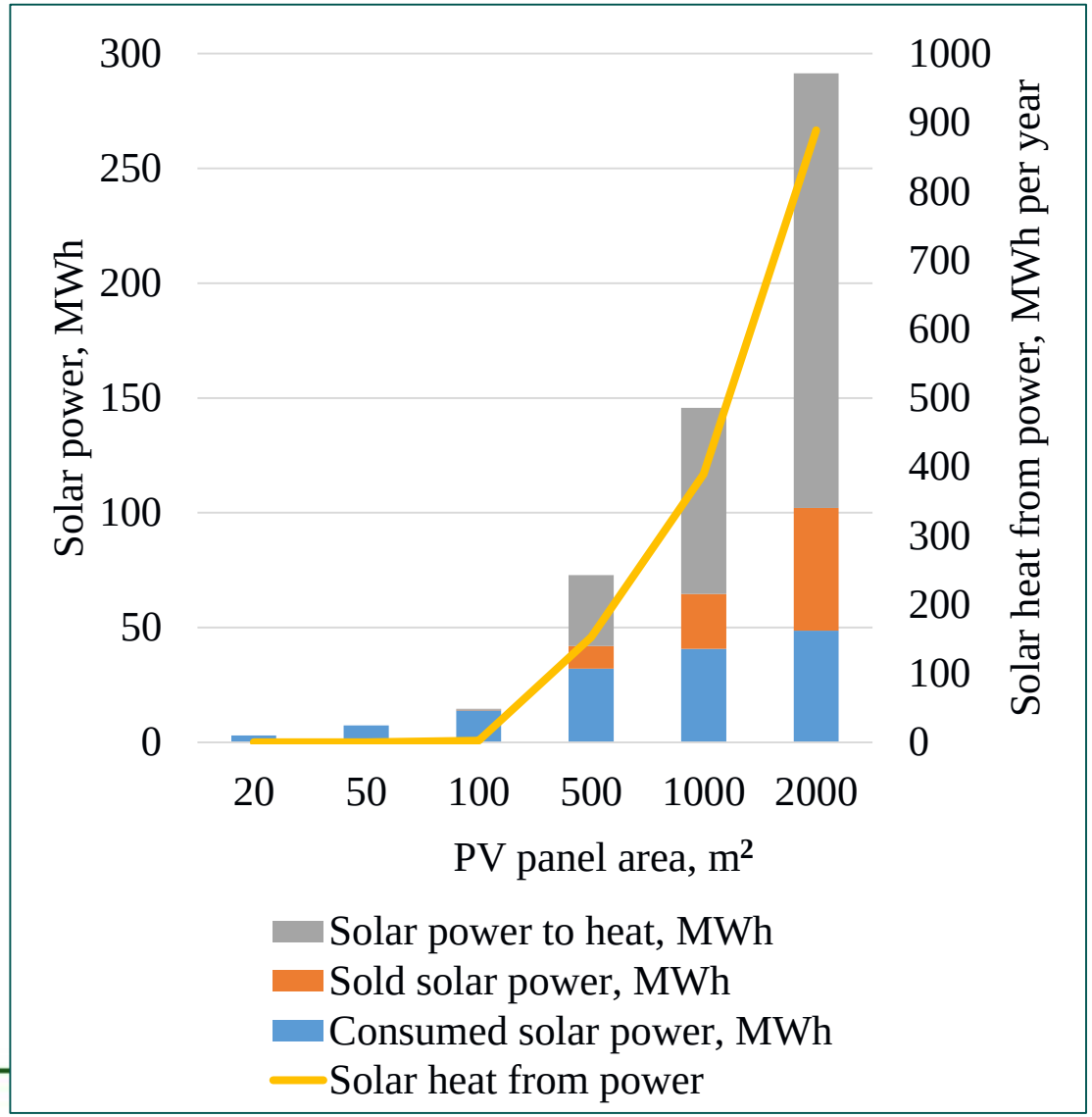
Energy production

Solar collector model

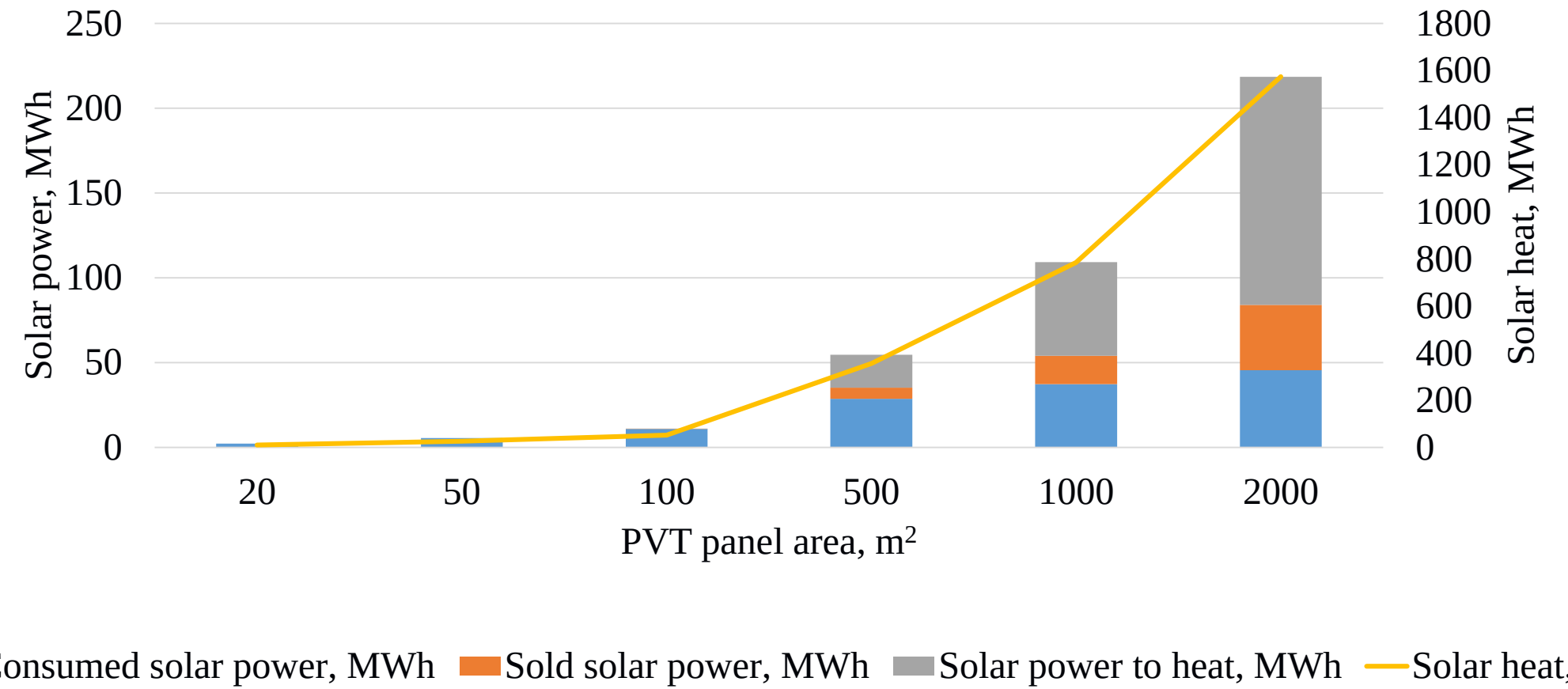


PV panel model

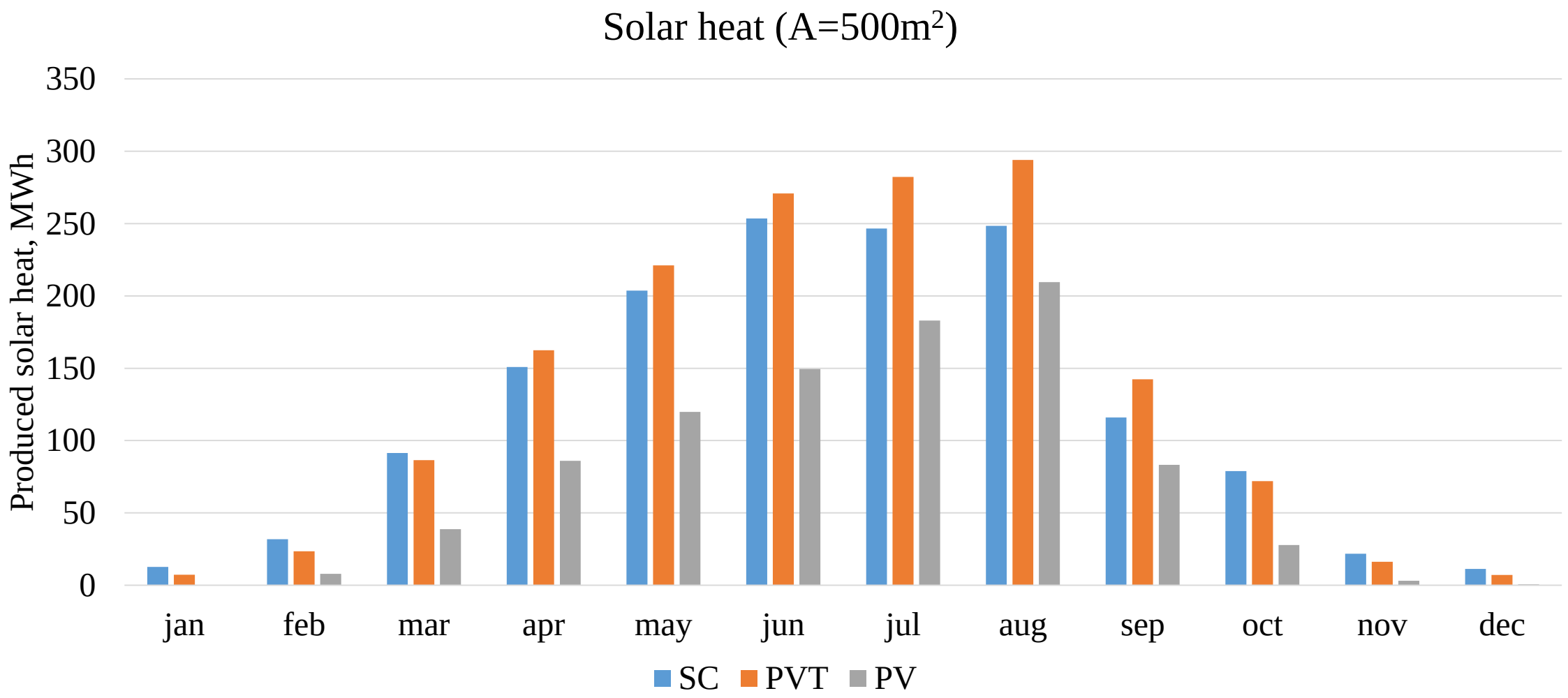




PV thermal panel model



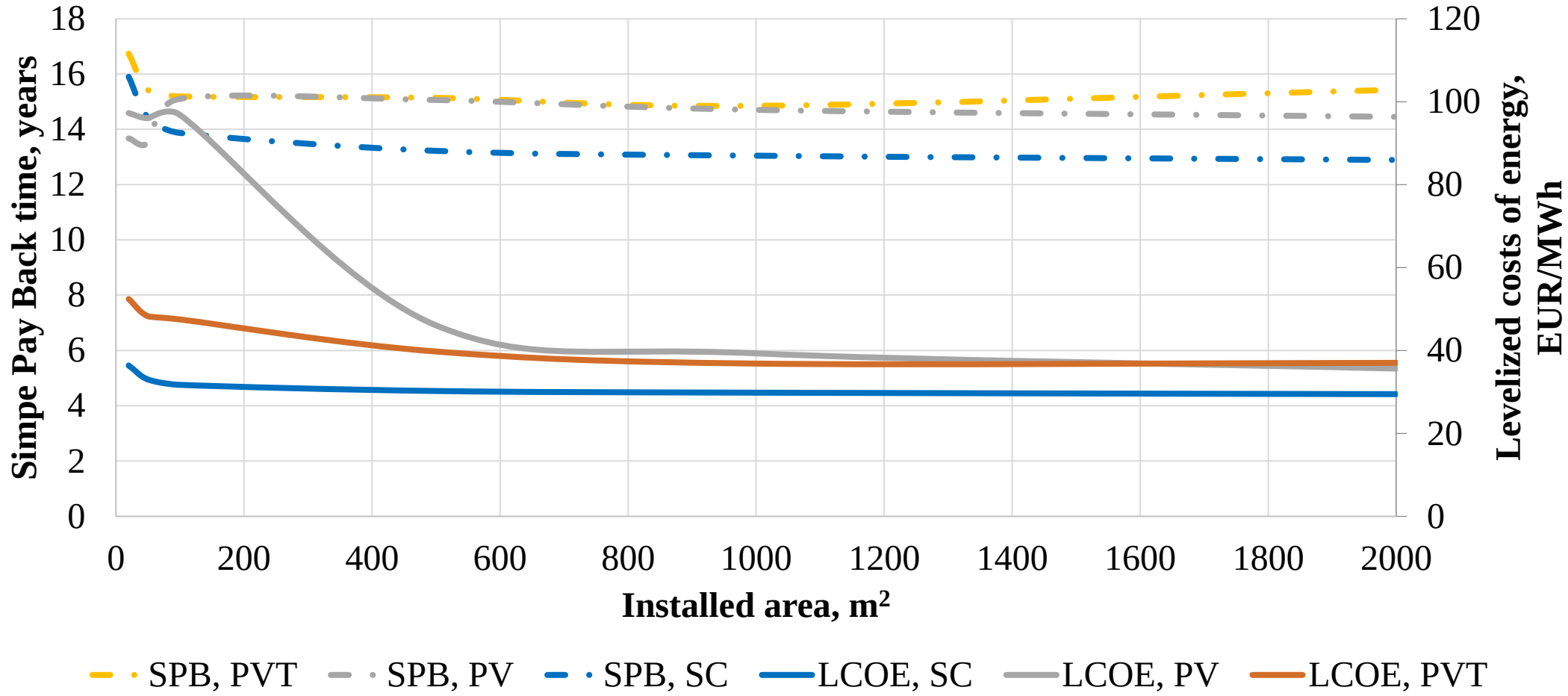
Comparison. Example



Analysis of economical, technological and environmental indicators

- Simple payback time
- Levelised costs of energy
- Useful exergy
- Specific useful exergy
- Avoided GHG emissions
- Costs of avoided GHG emissions
- etc

Economical analyses



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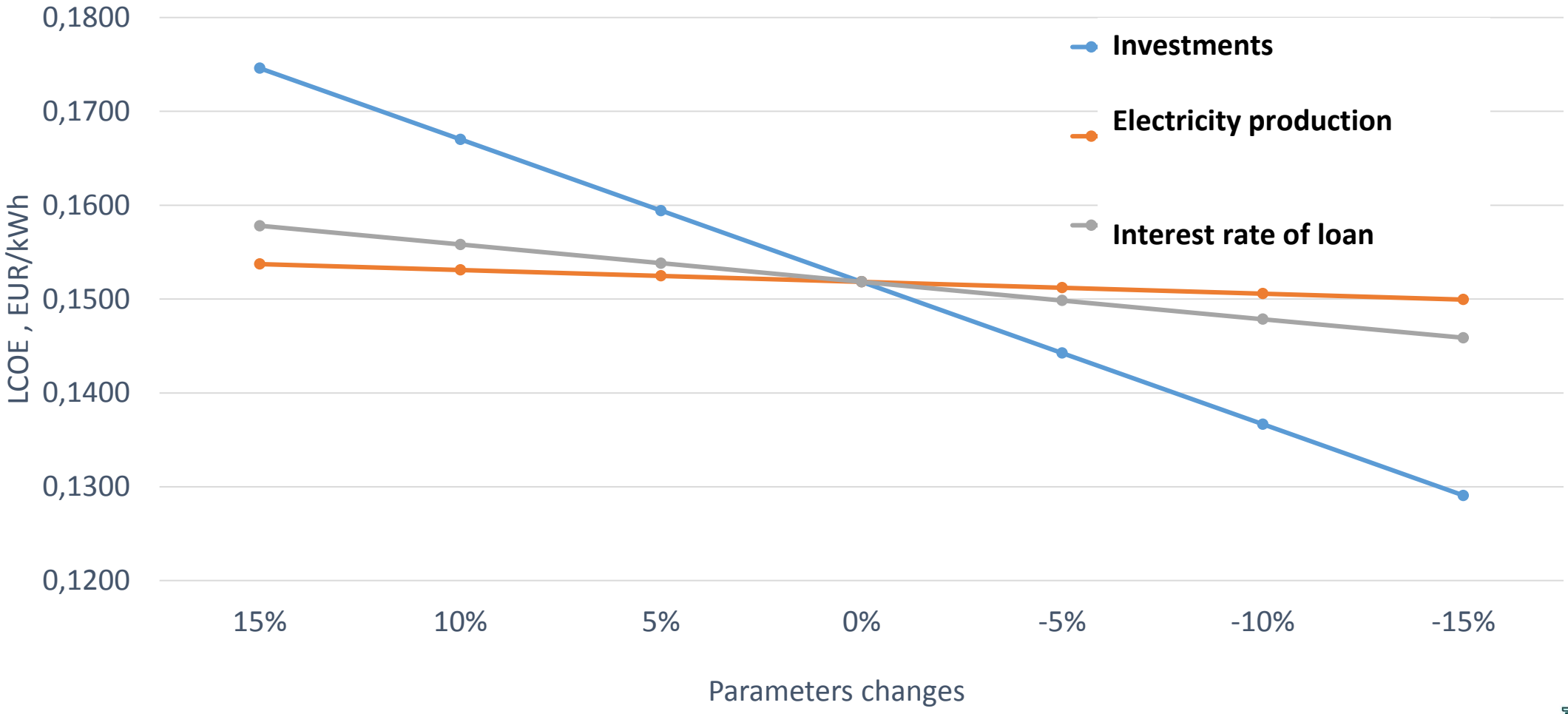
Sensitivity analysis

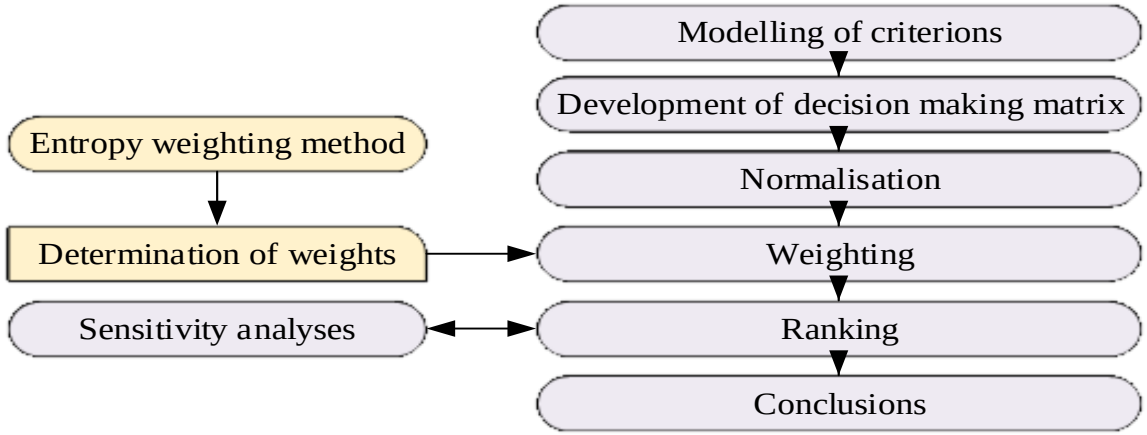
- Temperature changes
  - Specific useful exergy
- Heat tariff changes
  - Simple payback time
- Technology costs and power price
  - Simple payback time

LCOE sensitivity analysis. Case PV (200kW)



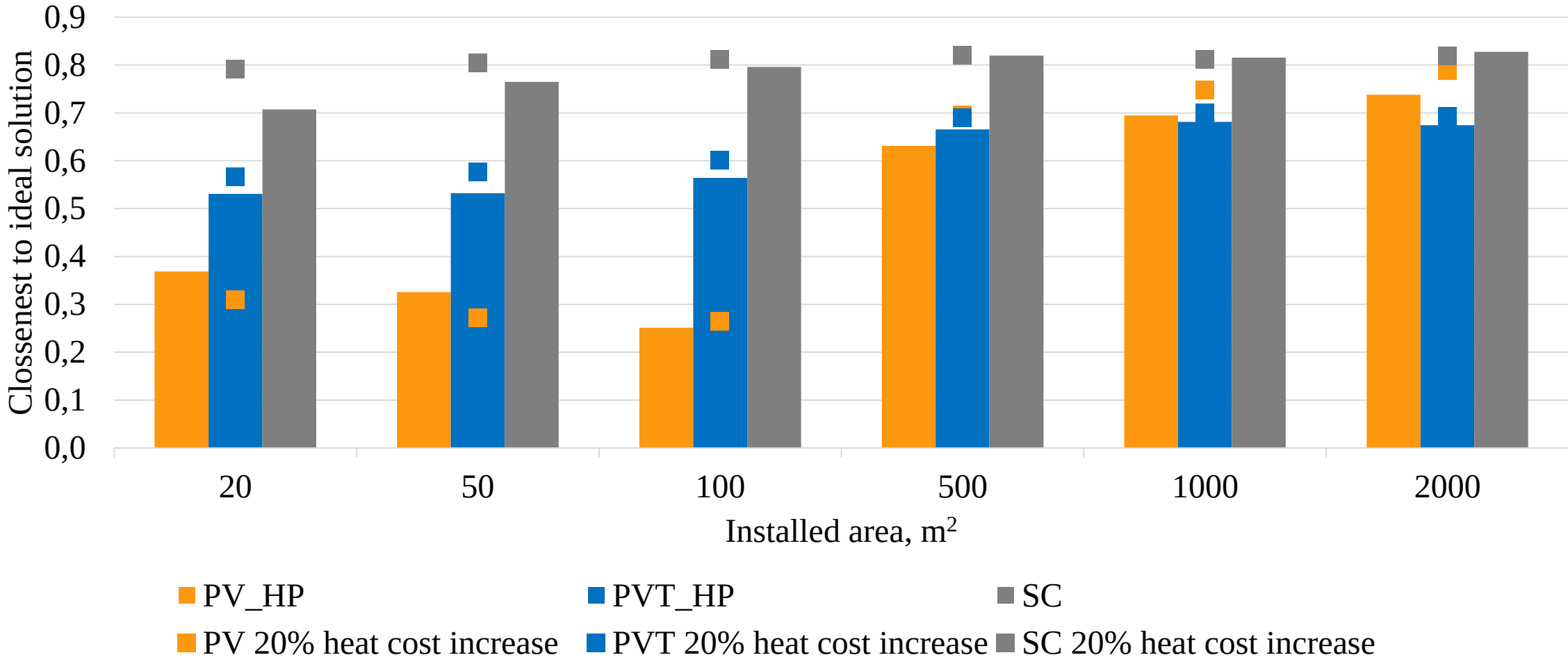
Multicriteria Analysis

Multicriteria analyses aplication



Scenario	Solar factor	Total savings, EUR/m²	NPV, EUR/m²	Specific useful exergy, kWh per EUR	LCOE, EUR/MWh	Total costs, EUR/m²	PBT, years	Specific operation costs, EUR/MWh	Cost of avoided CO_2, EUR/ kg_{CO2}
PVT HP	1,90%	41	37	1,10	39,8	622	15	7	3,6
PV HP	0,92%	24	0	0,96	46,1	366	15	10	4,2
SC	1,80%	33	88	1,44	30,2	437	13	7	2,7
Entropy weights	0,11	0,11	0,09	0,12	0,12	0,12	0,10	0,11	0,12

Multi-criteria analyses results



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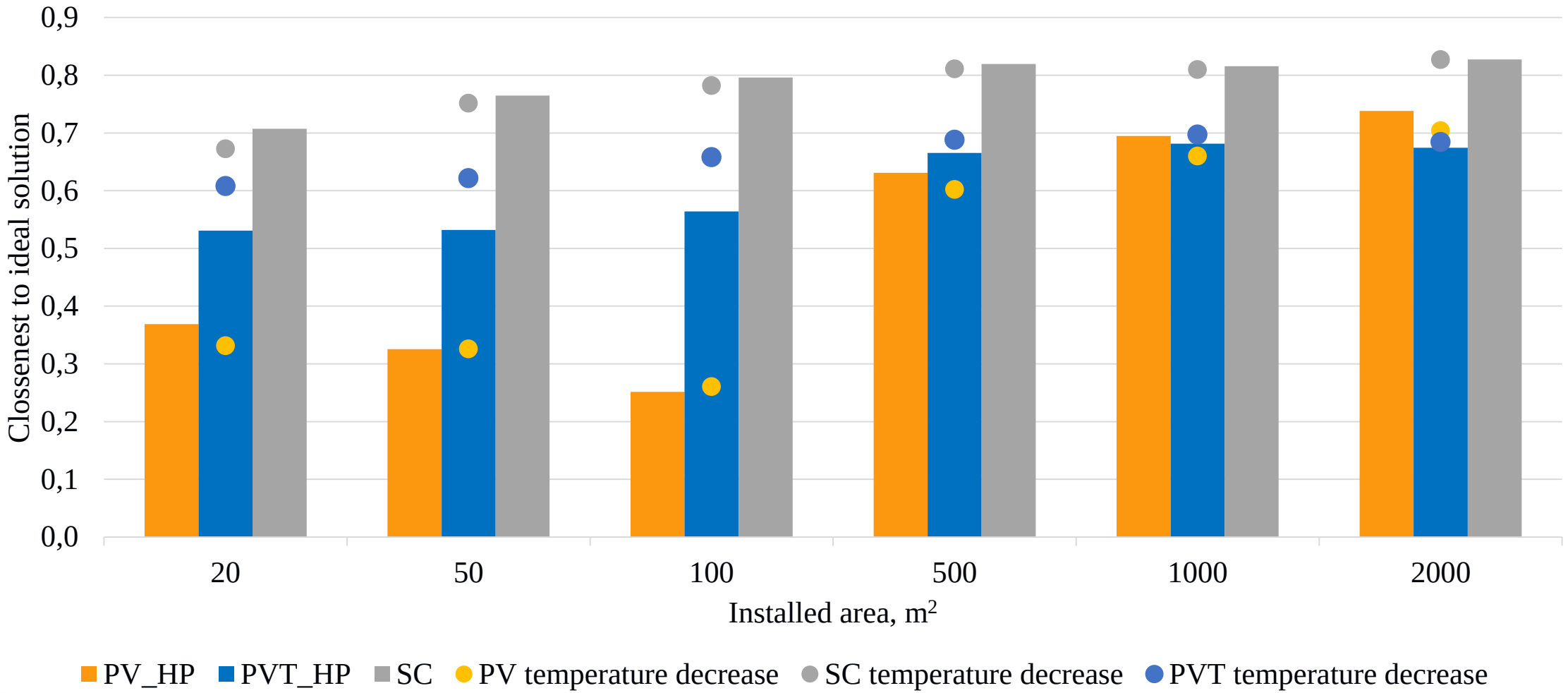
Multi-criteria analyses results



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Conclusions (1)

1. Solar systems can bring **the economical benefit and flexibility increase** for convencial DH system development as it allows to divers the energy sources in total energy balance

2. **Solar collectors** has been identified as a most desirable solution because of low capital costs. However, the results can be impacted by the power and heat price increase and decrease in technology costs.

3. Introduction of **P2H concept** for surplus solar power allows to identify **most suitable energy production strategy** by taking into account the economical conditions (power and heat prices).

Conclusions (2)

4. **Changes in the price** of heat tariff affect both the economic savings and the share of heat converted. For example, if the price of heat falls by 20%, most of the remaining electricity from PVT panels is sold rather than transformed into heat (P2H).

5. **Lowering the temperature** of the heat carrier affects the efficiency of the solar collectors and the COP of the heat pump. Lowering the temperature affects the amount of energy produced, and thus the specific energy costs as well as the total and specific exergy.

Solar collectors

Solar PV

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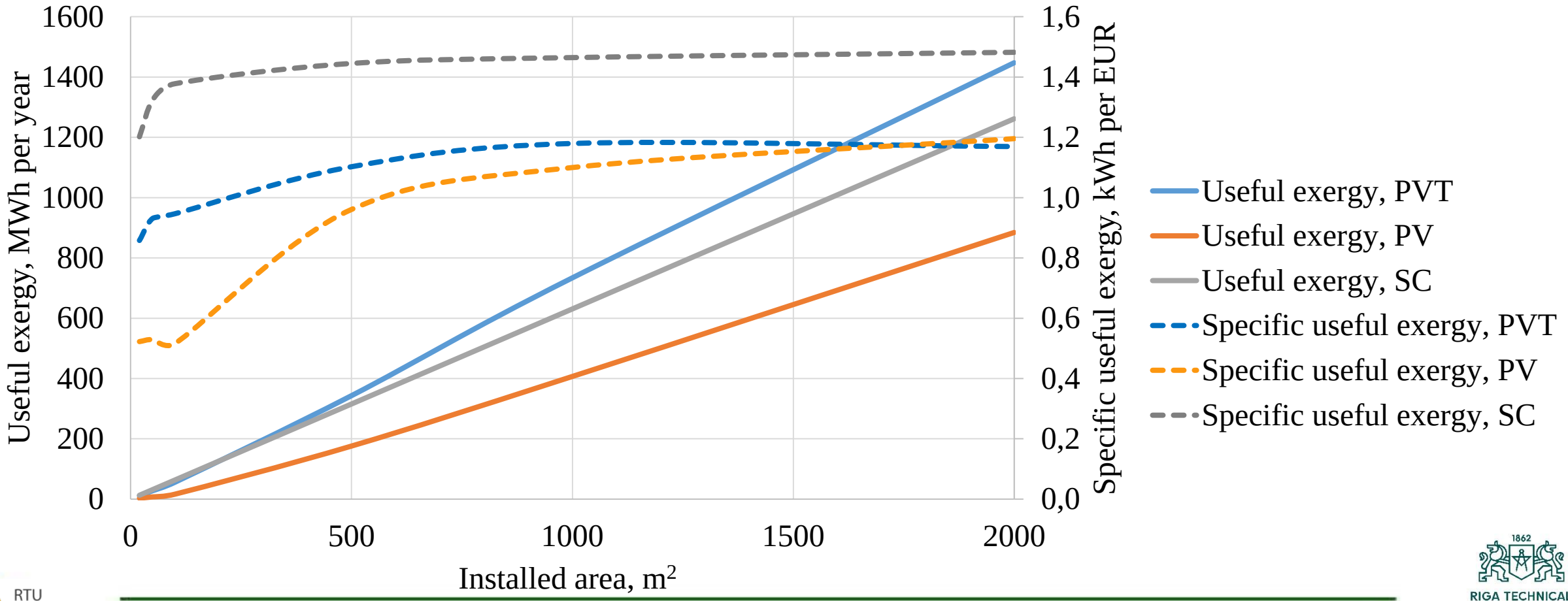
Economical and Environmental Analysis

Useful exergy and specific useful exergy per system costs



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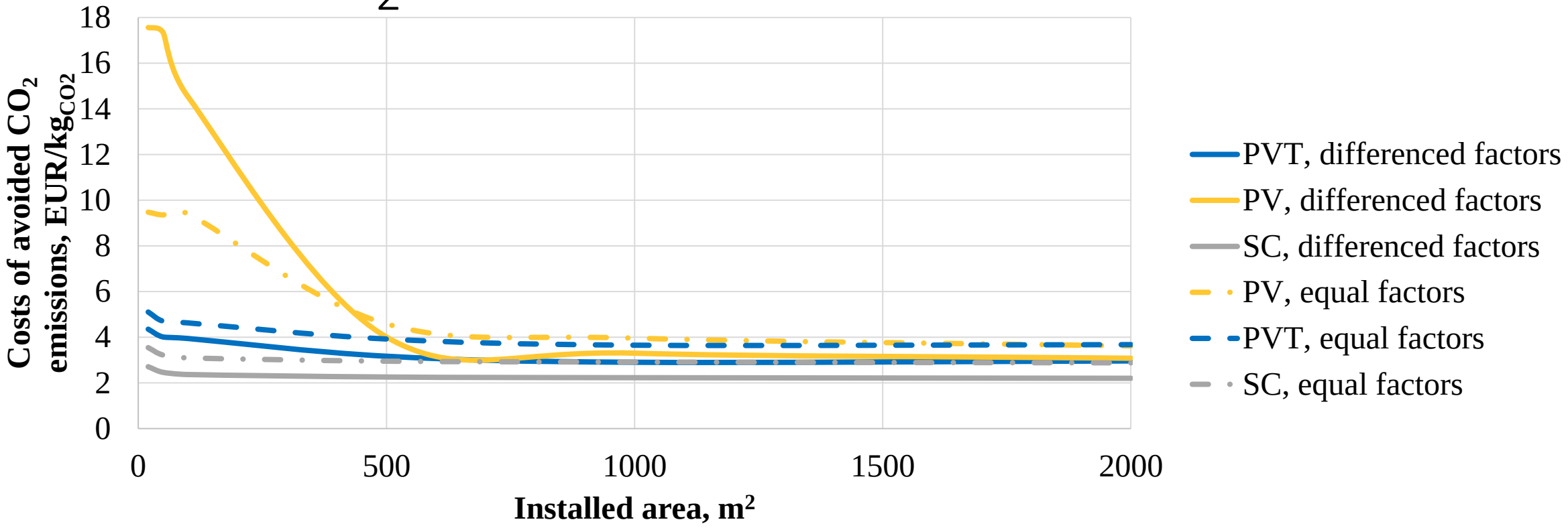
Avoided CO_2 emissions



CO_2 factors	
Electricity from grid, kg CO_2/MWh	109
Heat from DH, kg CO_2/MWh	264
Equl factors (natural gas),kg CO_2/MWh	220

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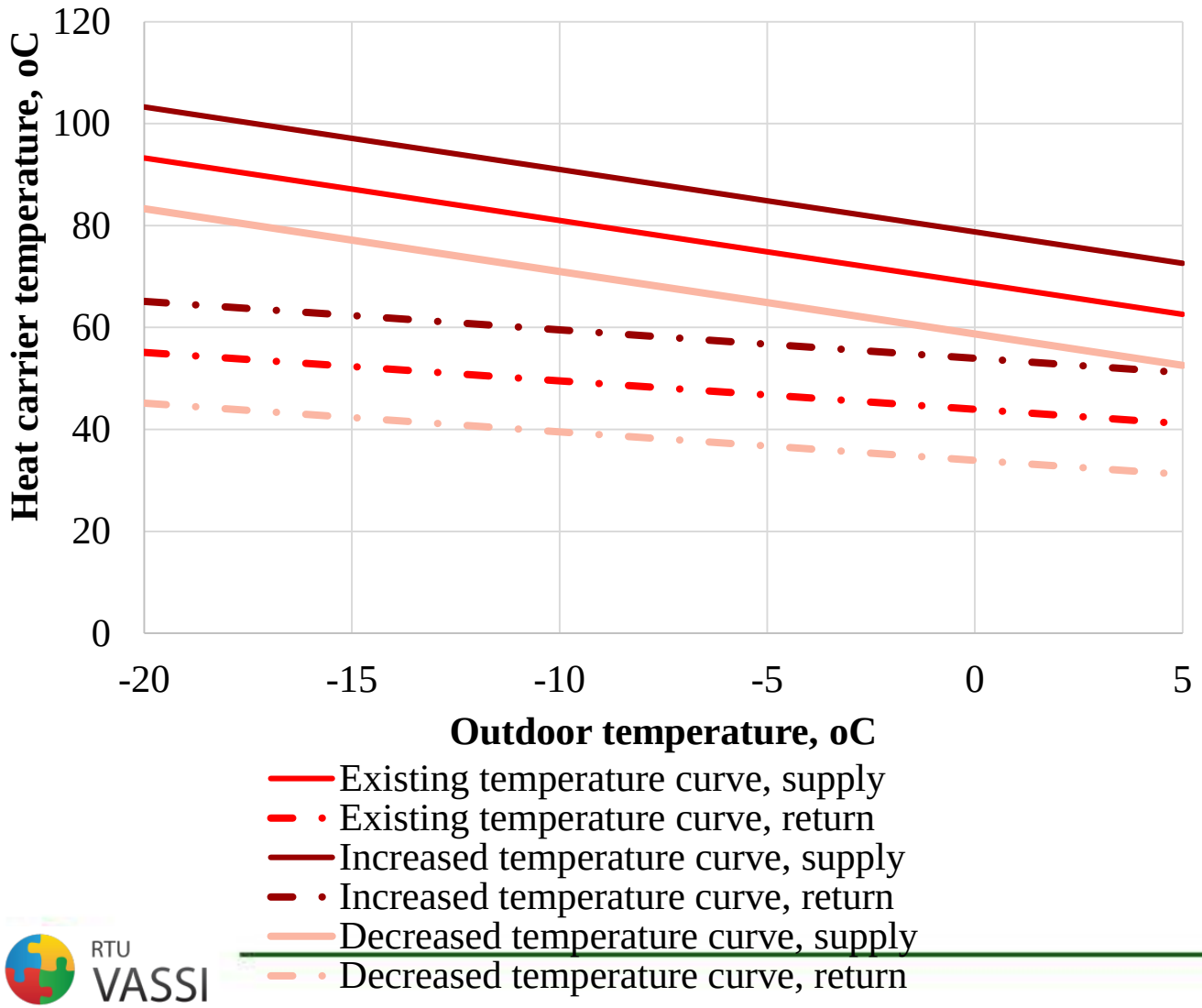
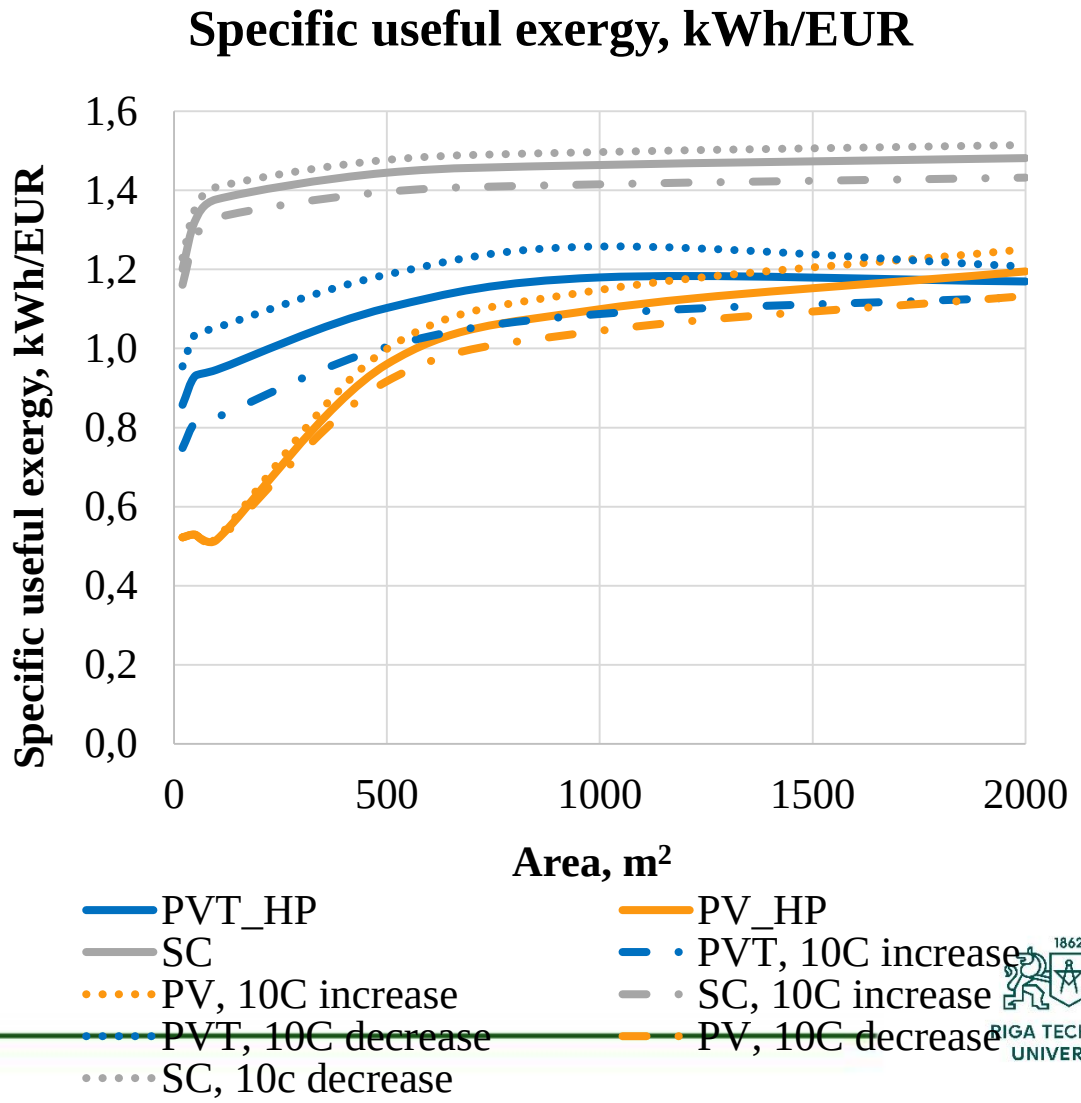
Sensitivity Analysis

Sensitivity analyses: Heat carrier temperature





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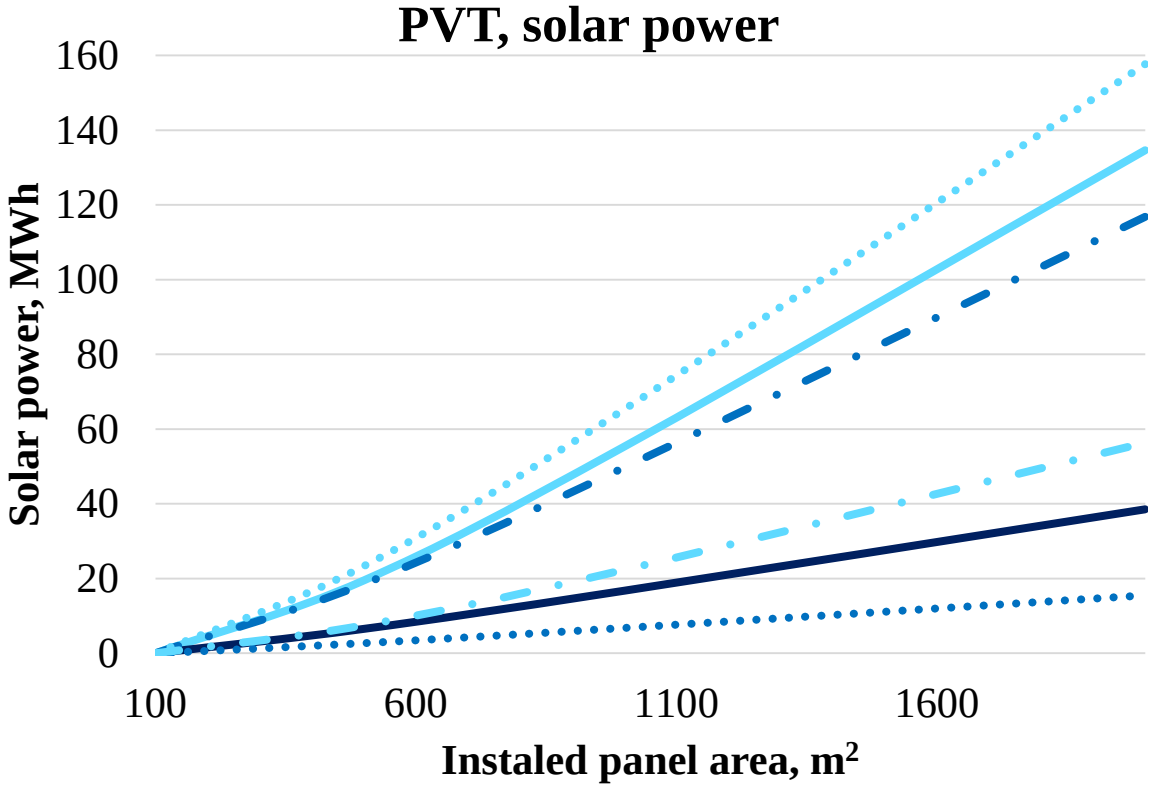
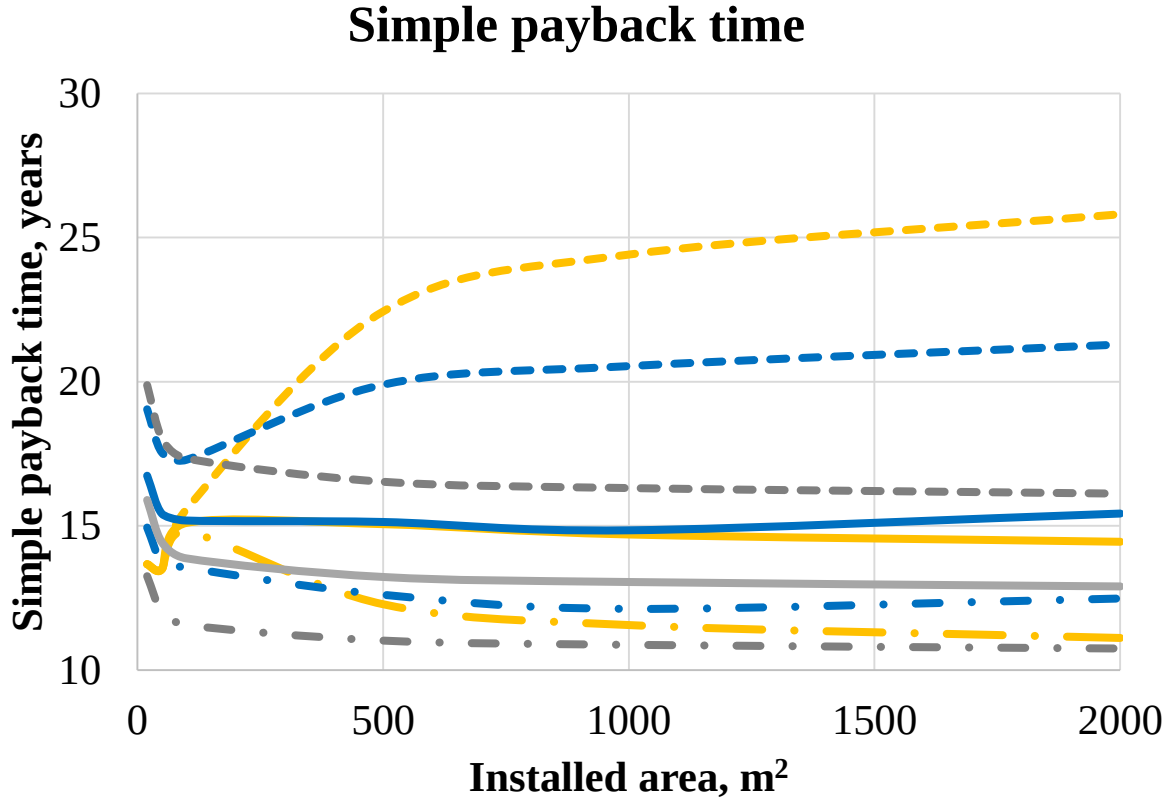
Sensitivity analyses: Heat tariff





- P2H
- Sold solar power
- Sold solar power, 20% heat cost increase
- Sold solar power, 20% heat costs decrease
- P2H, 20% heat costs increase
- P2H, 20% heat costs decrease
- PV
- PV, 20% heat cost decrease
- PV, 20% heat cost increase
- PVT
- PVT, 20% heat cost decrease
- PVT, 20% heat cost increase
- SC
- SC, 20% heat cost decrease
- SC, 20% heat cost increase

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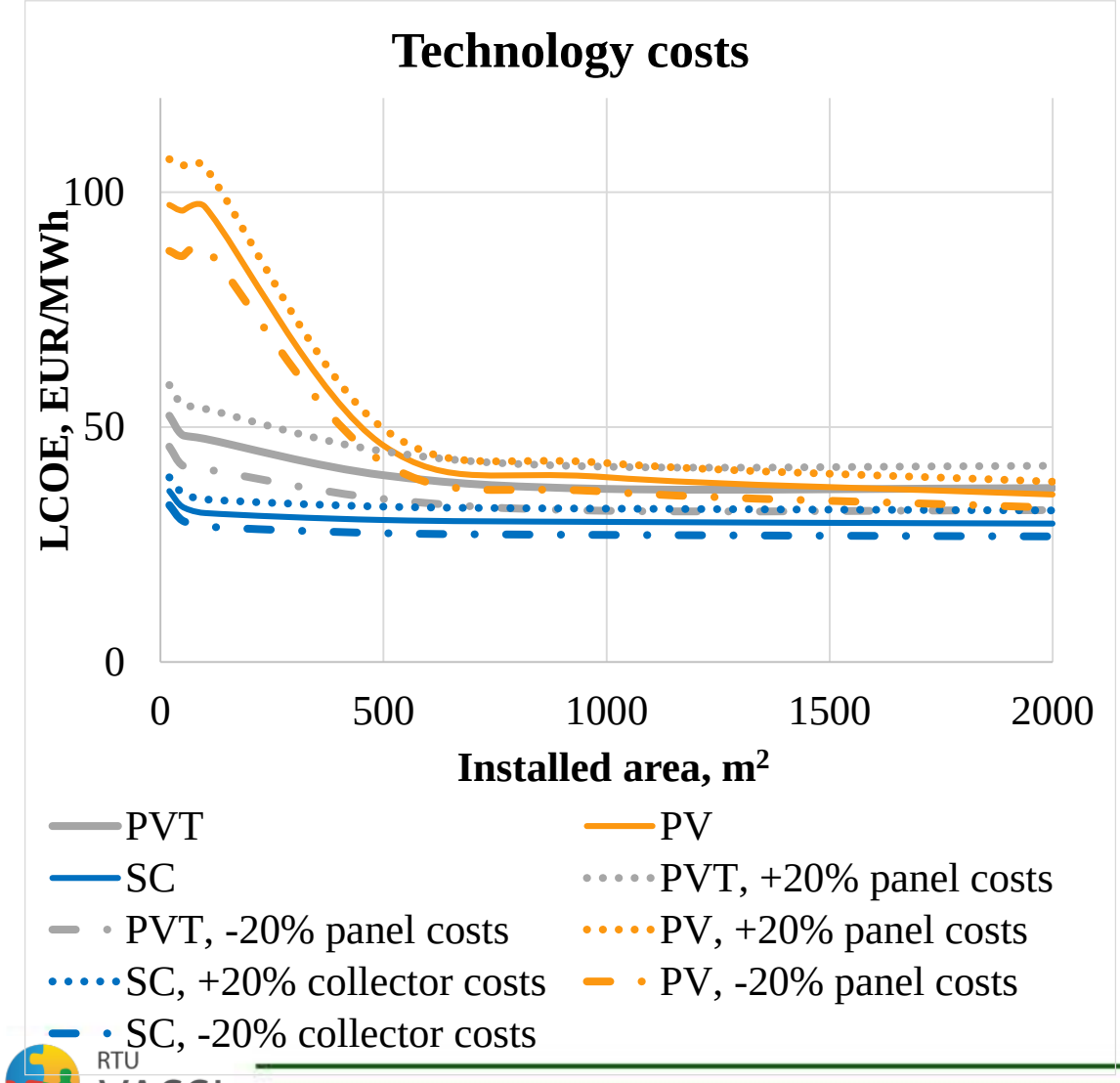
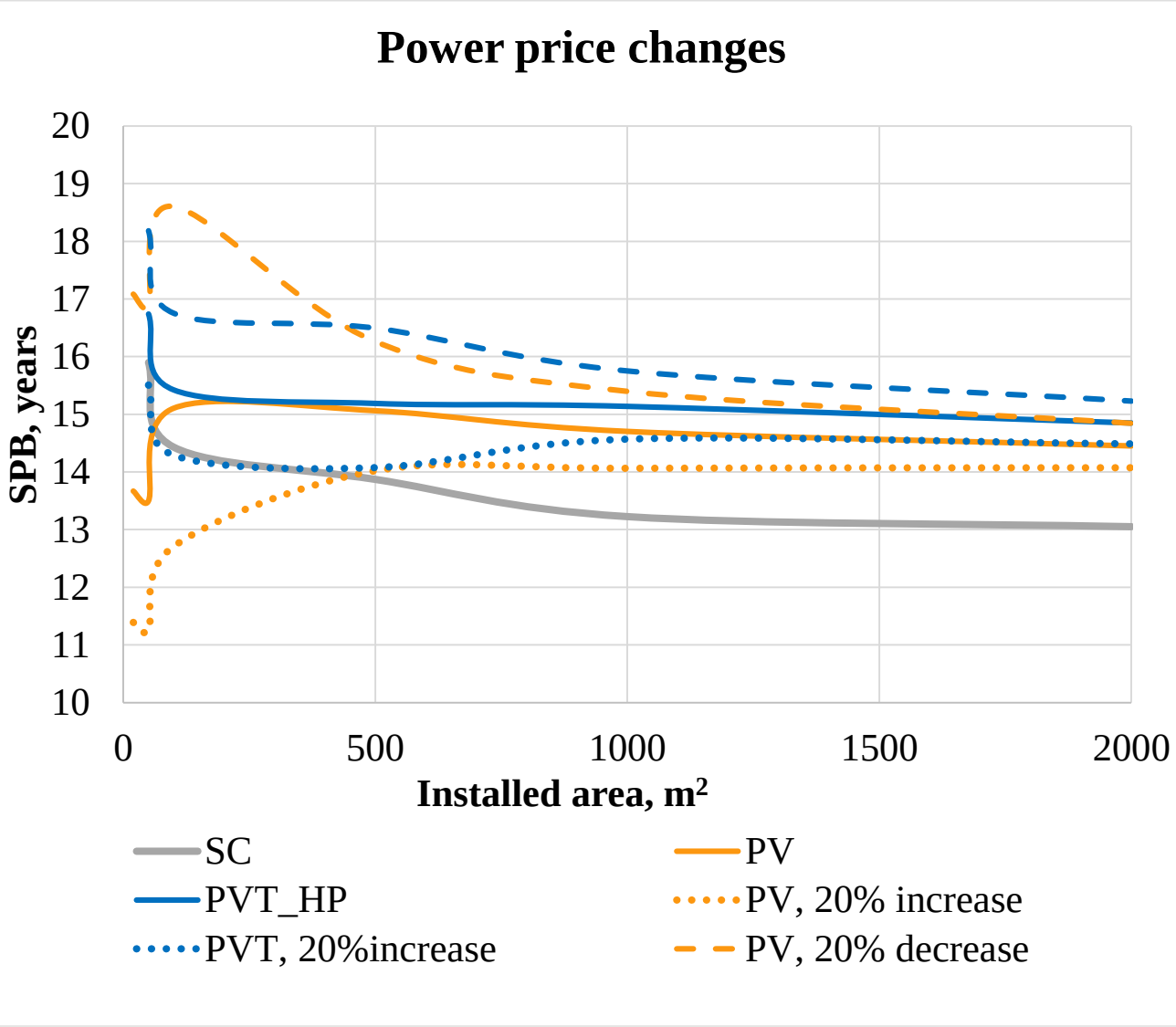
Sensitivity analyses: Technology costs and power price





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