VDI Wissensforum

RES4LIVE

ENERGY SMART LIVESTOCK FARMING
TOWARDS ZERO FOSSIL FUEL CONSUMPTION

COST-EFFECTIVE IMPLEMENTATION OF RENEWABLE ENERGY SOURCES IN LIVESTOCK BARNS

23/11/2022

Paper by: Willem Faes, prof. Steven Lecompte, Jarissa Maselyne

Speaker: Manon Everaert

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101000785

RES4LIVE PROJECT

- **R**enewable **E**nergy **S**ources for **LIVE**stock
- 17 partners from 8 countries
- October 2020 – 2024
- Horizon 2020

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- **R**enewable **E**nergy **S**ources for **LIVE**stock
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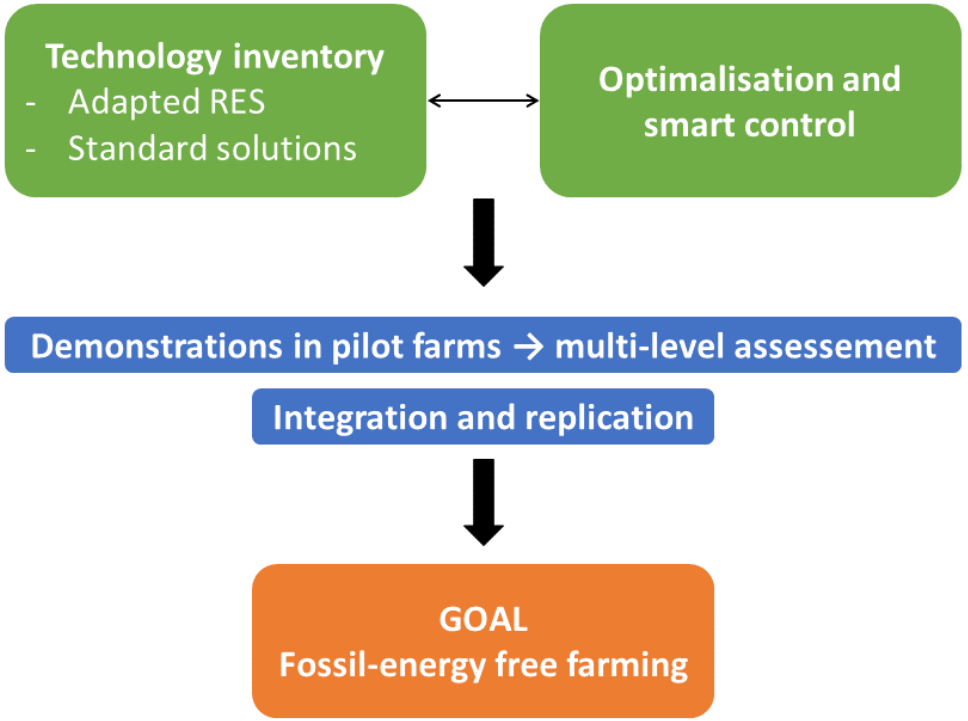

Policy
Social
Stakeholders
Engagement

https://res4live.eu/

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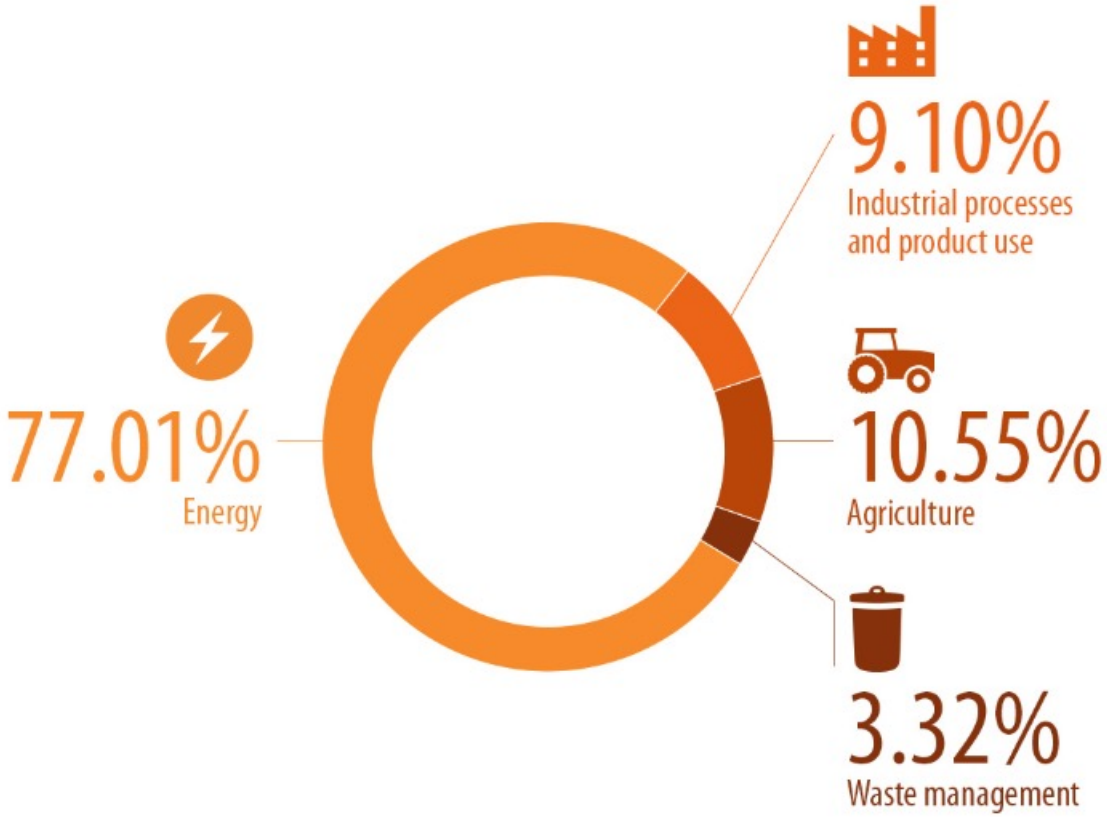
RES4LIVE: THE ISSUE

Greenhouse gas emissions by sector in the EU (2019)



https://www.europarl.europa.eu/

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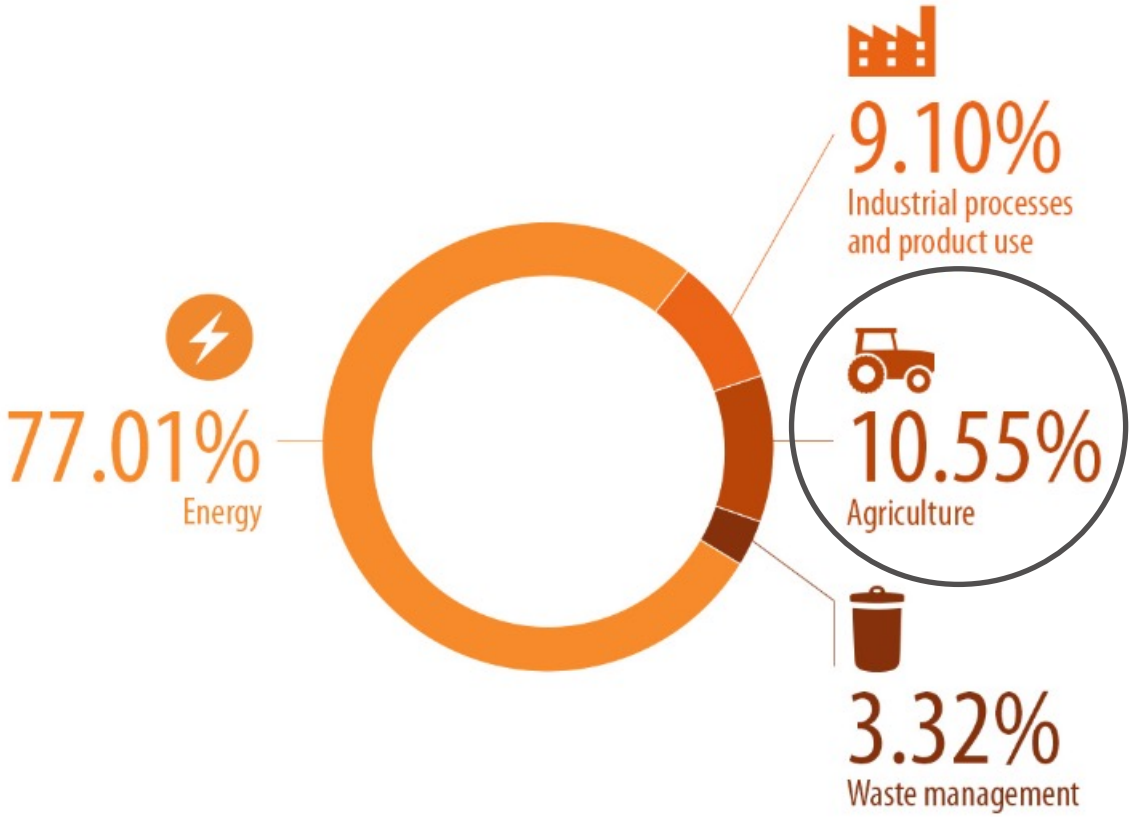

40% is livestock

https://www.europarl.europa.eu/

https://eu.boell.org/

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RES4LIVE: PILOT FARMS

Pig meat

Cow milk

Chicken meat

Pig meat

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RES4LIVE: PILOT FARMS

Pig meat

Chicken meat

Cow milk

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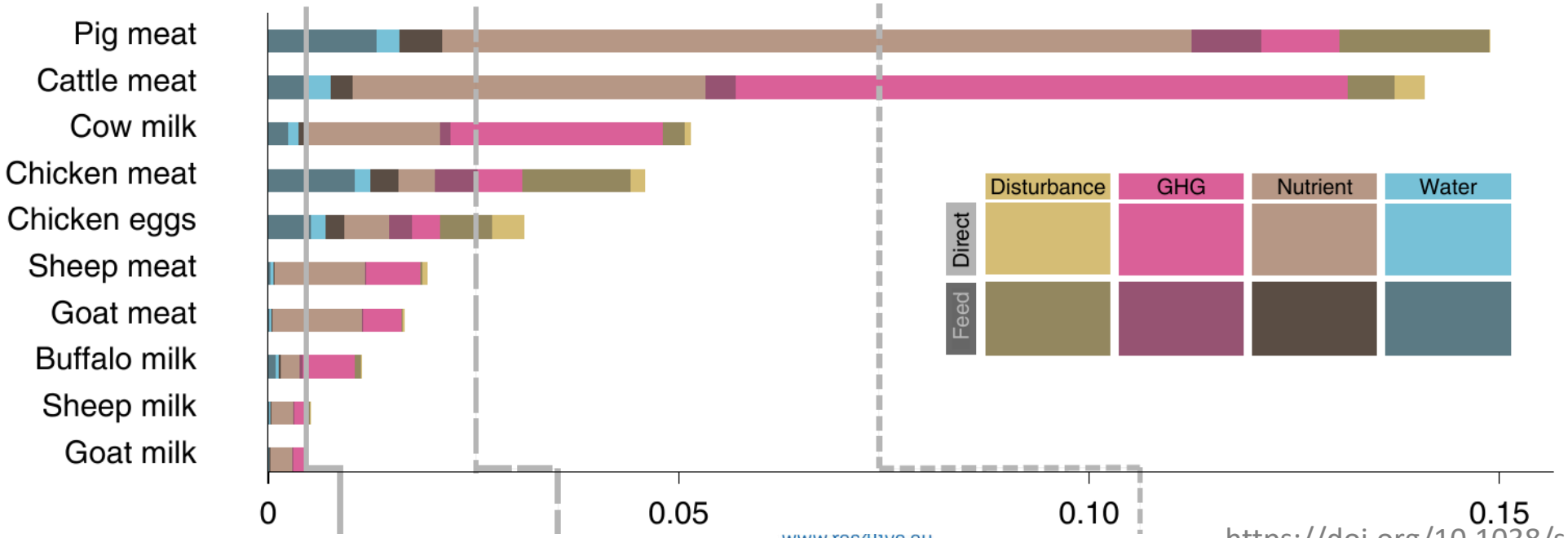
Environmental pressure of different livestock



https://doi.org/10.1038/s41893-022-00965-x

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OUR PURPOSE WITHIN RES4LIVE

1. Simulation
    - Insert RES
    - Life-cycle costs (LCC) and greenhouse gas emissions (GHG)
2. Apply to pig farm in Belgium

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3. Test and demonstrate
4. Extend to other (pilot) farms

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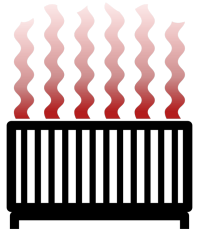
ENERGY DEMAND IN PIG FARMING

- Heating
  - Air
  - Floor
  - Sanitary
  - Heat canon



- Electricity
  - Feeding
  - Ventilation
  - Lighting
  - Heating lamps

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RENEWABLE ENERGY SOURCES (RES)

- Solar energy
  - Photovoltaic (PV)
  - Solar thermal (ST)
  - PV thermal (PVT)

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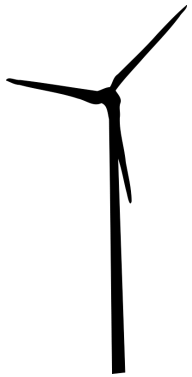
- Wind energy



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RENEWABLE ENERGY SOURCES (RES)

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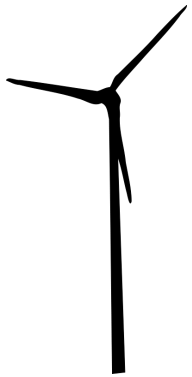
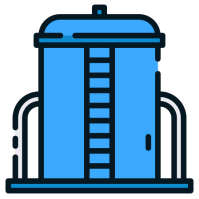
- Wind energy
- Energy collectors





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RENEWABLE ENERGY SOURCES (RES)

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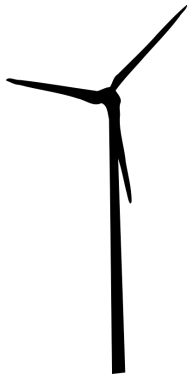
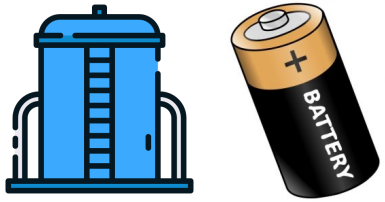
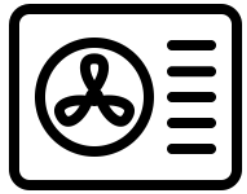
  - PV thermal (PVT)
- Wind energy
- Energy collectors
- Heat pumps







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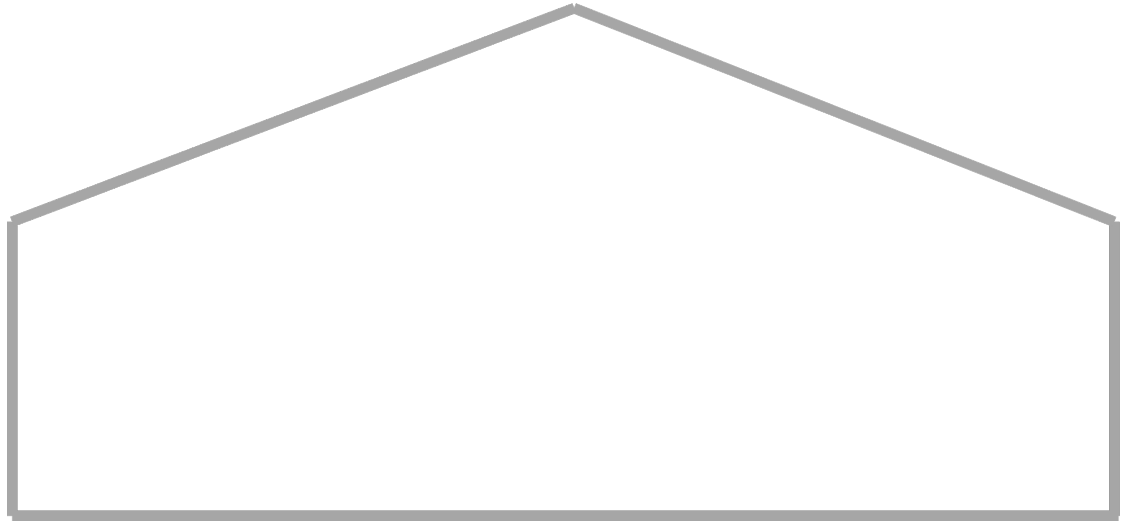
MODELLING APPROACH FOR ONE FARM

1. Steady-state model (Python)
2. Calculate current energy balance
   - Associated cost balance
   - GHG emissions
3. Implementation of RES with inputs
   - Energy demand
   - Local weather data



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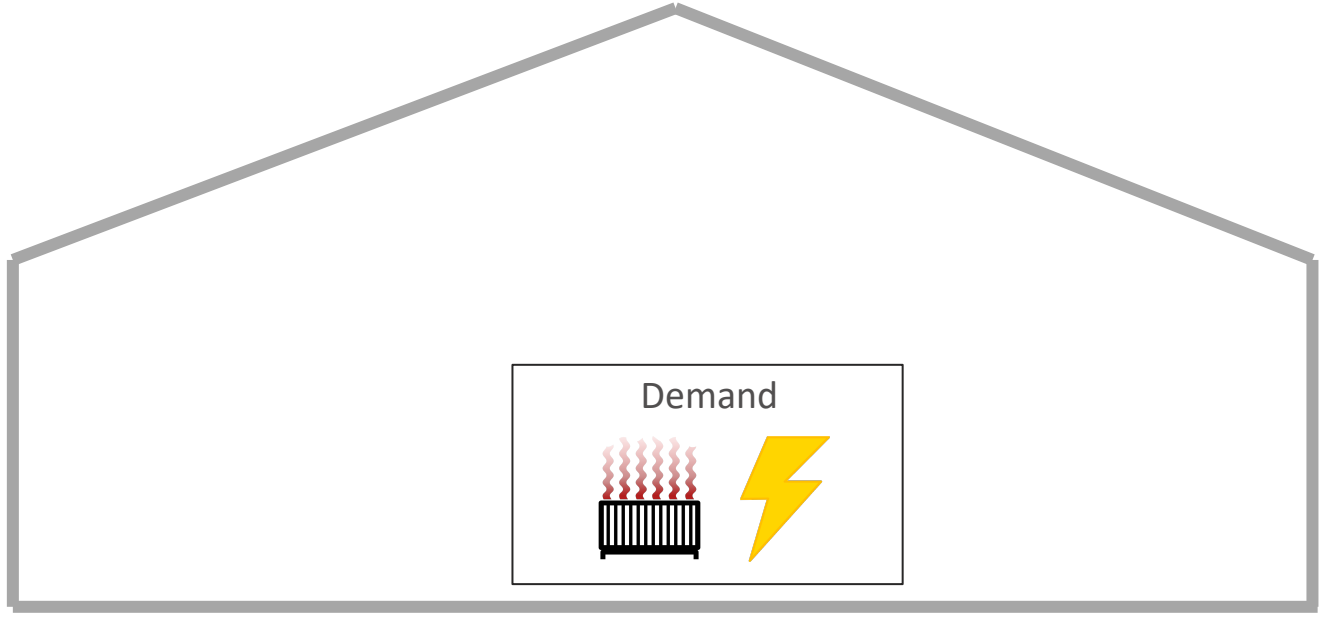

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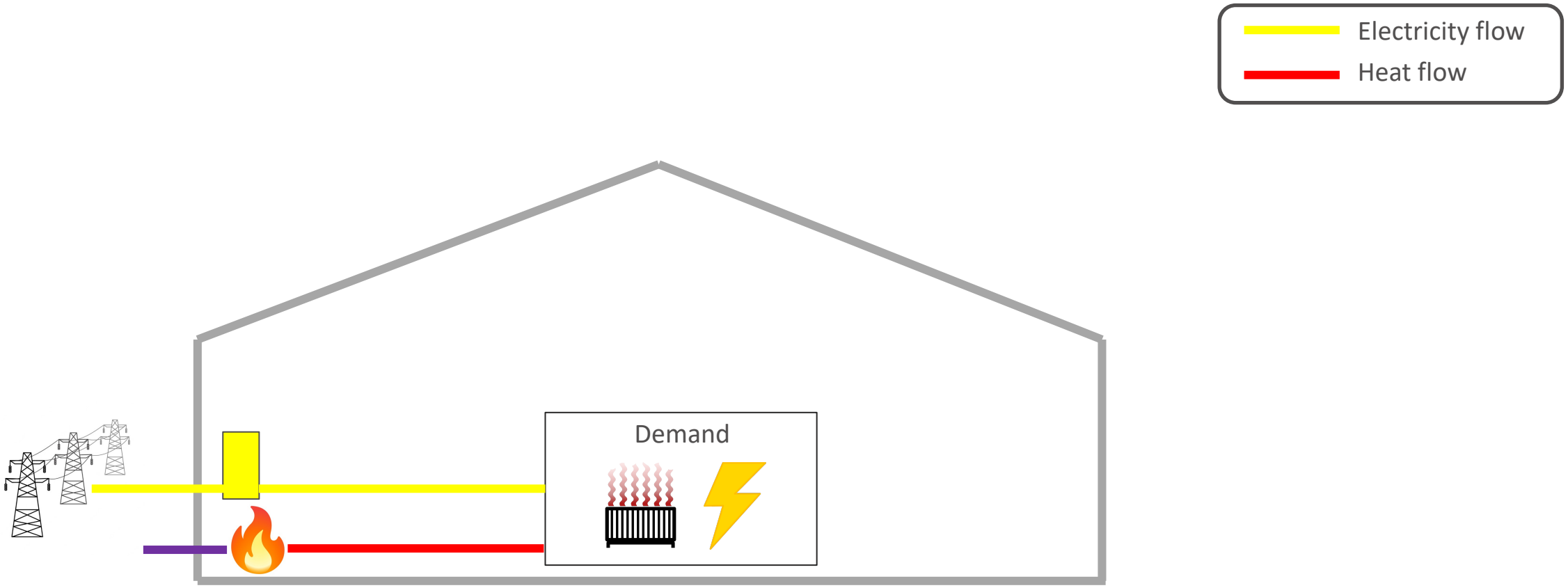

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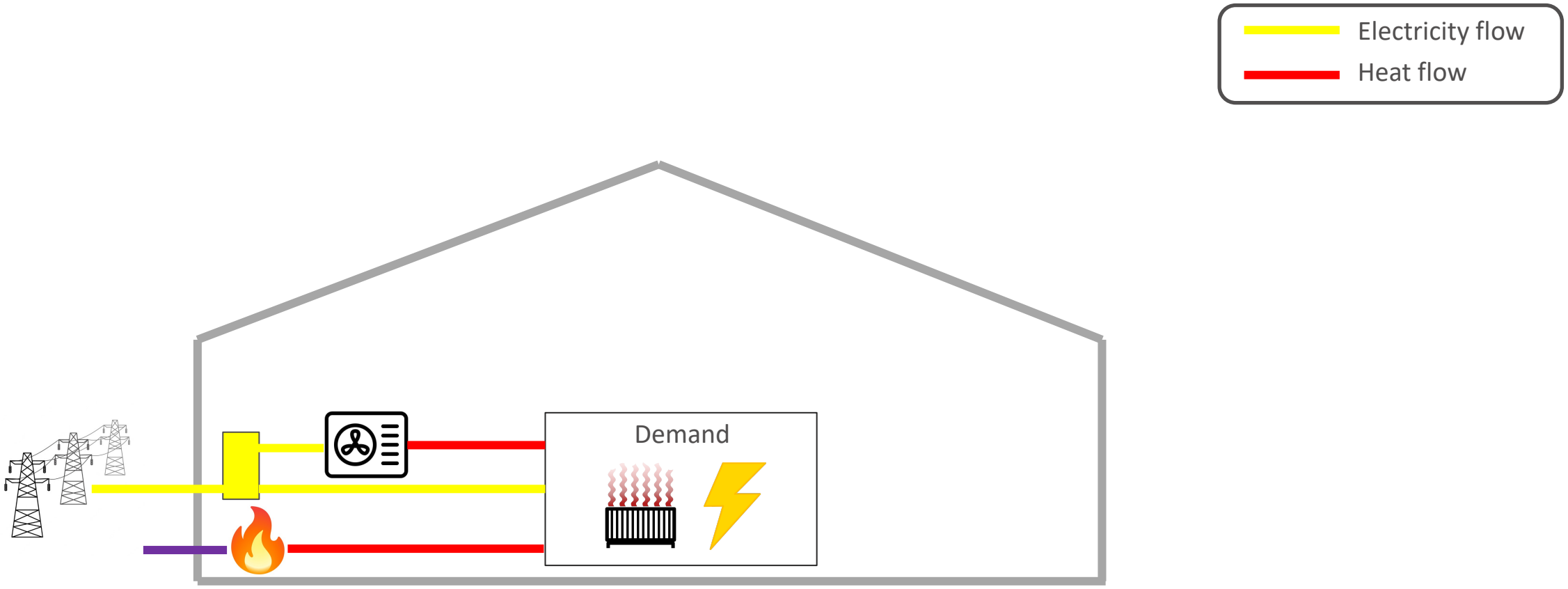

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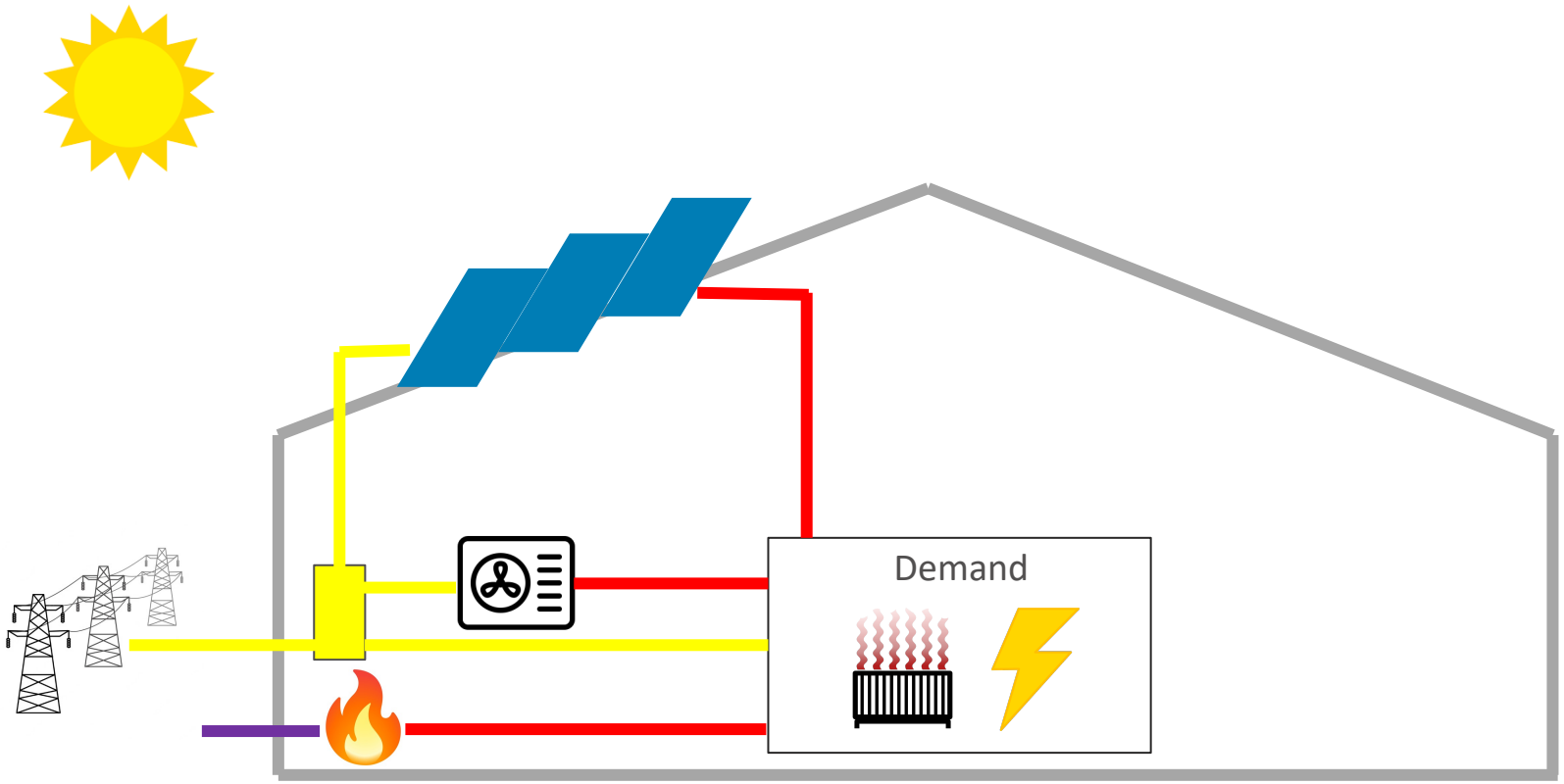

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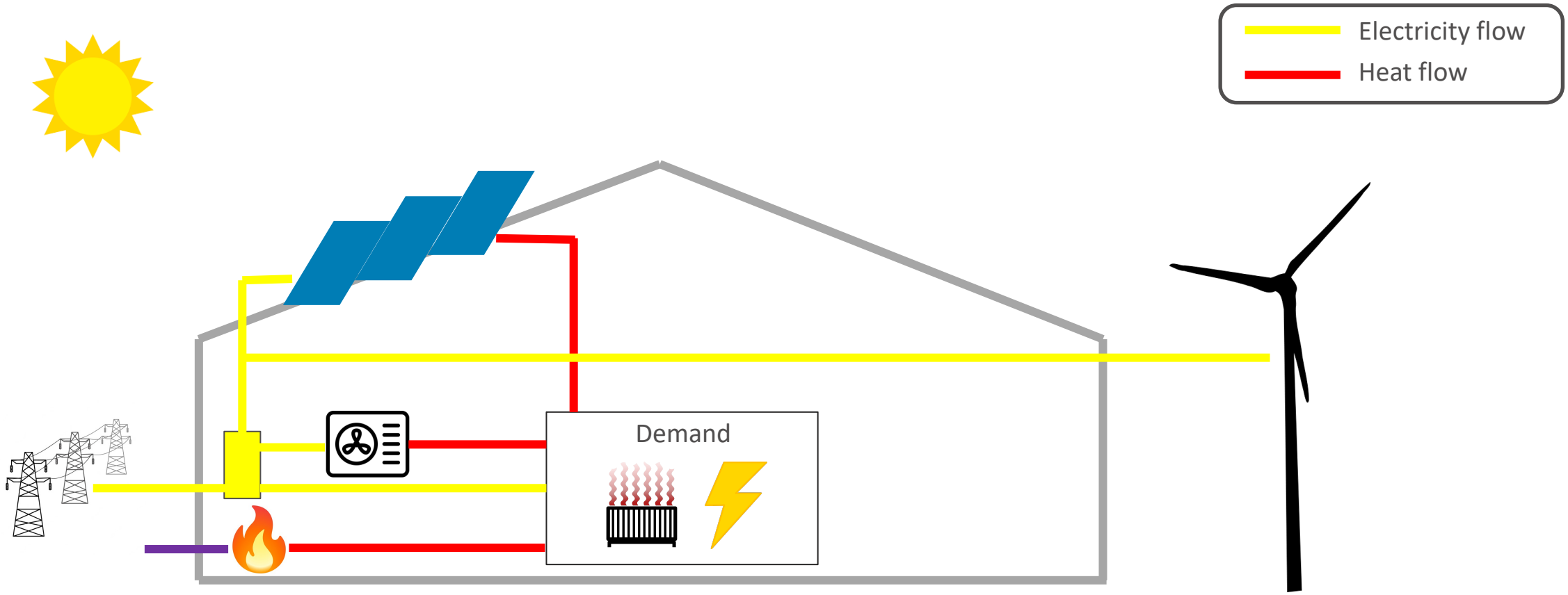

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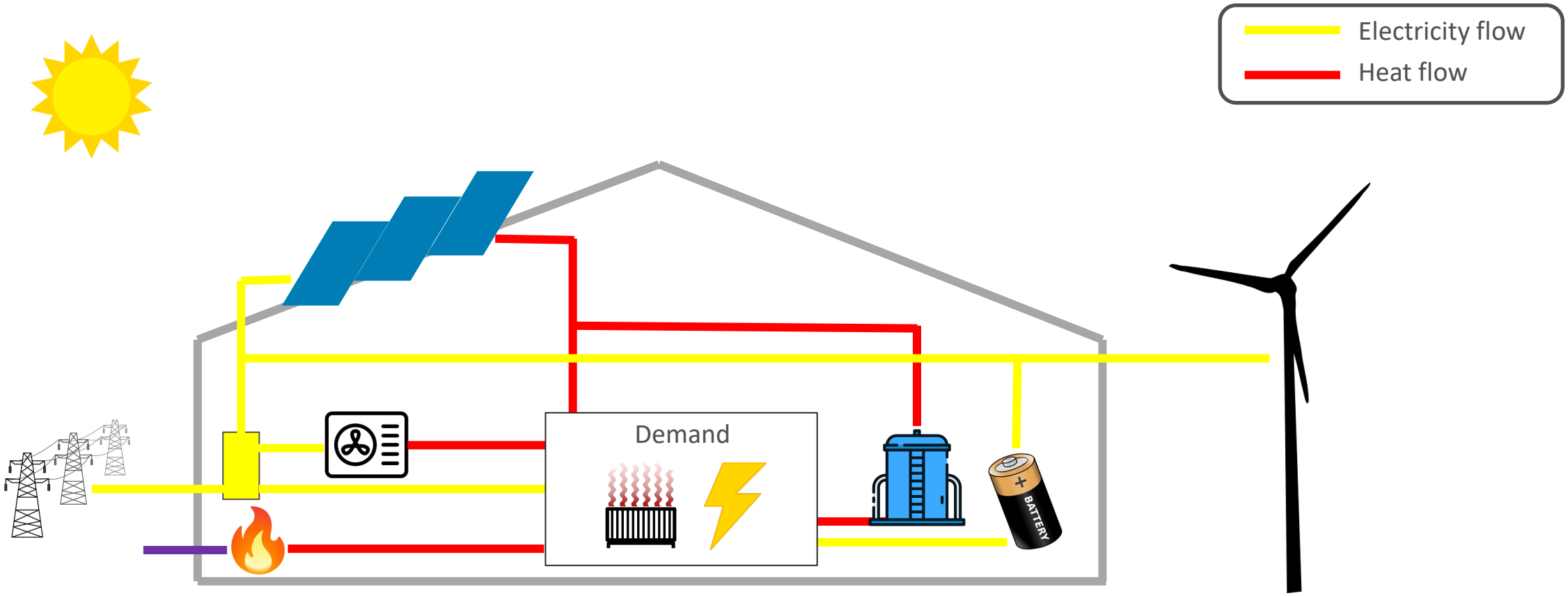

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EVALUATION CRITERIA

- Life-cycle cost (LCC) over 20 years
  - $LCC = IC_0 + \sum_{i=0}^{20} \frac{EC_i + IC_i}{(1+r)^i}$

IC	Investment cost
EC	Energy cost
r	Discount rate

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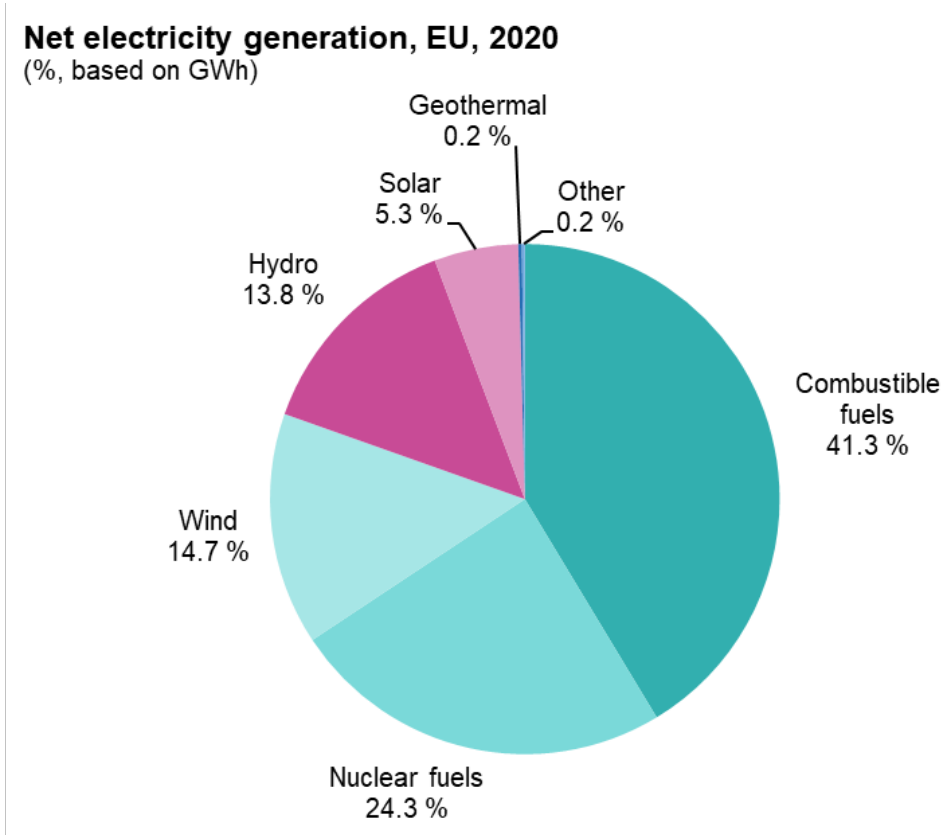
- Greenhouse gas emissions
  - Fuel combustion
  - Natural gas grid
  - Emissions related to electricity from grid



https://ec.europa.eu/eurostat/

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IMPLEMENTED COST FUNCTIONS

- Boiler: € 15k
- Wind turbines: € 60k per Unit

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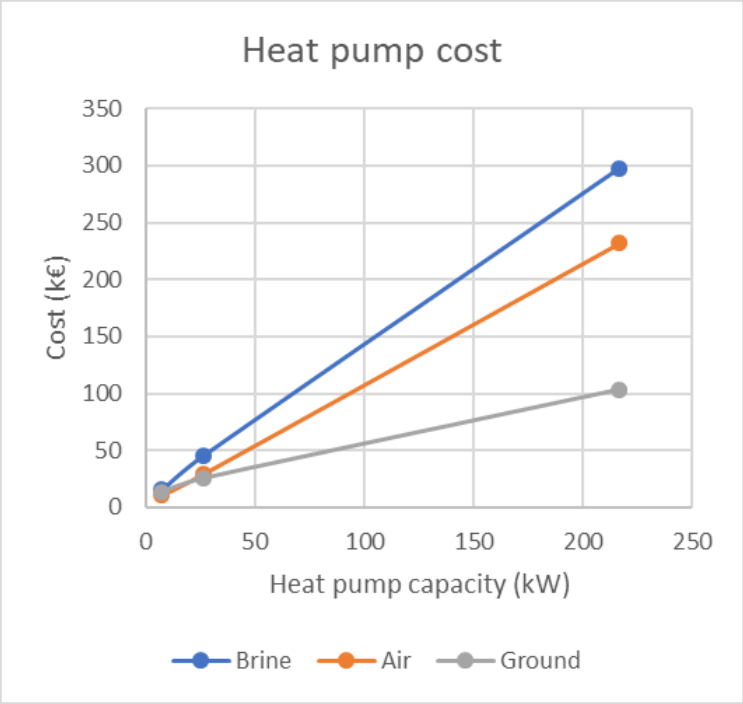

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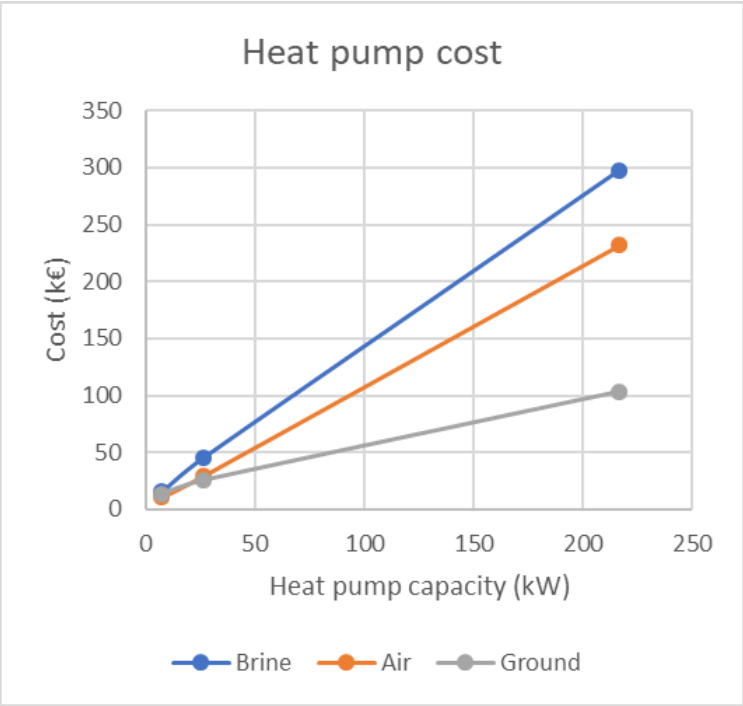

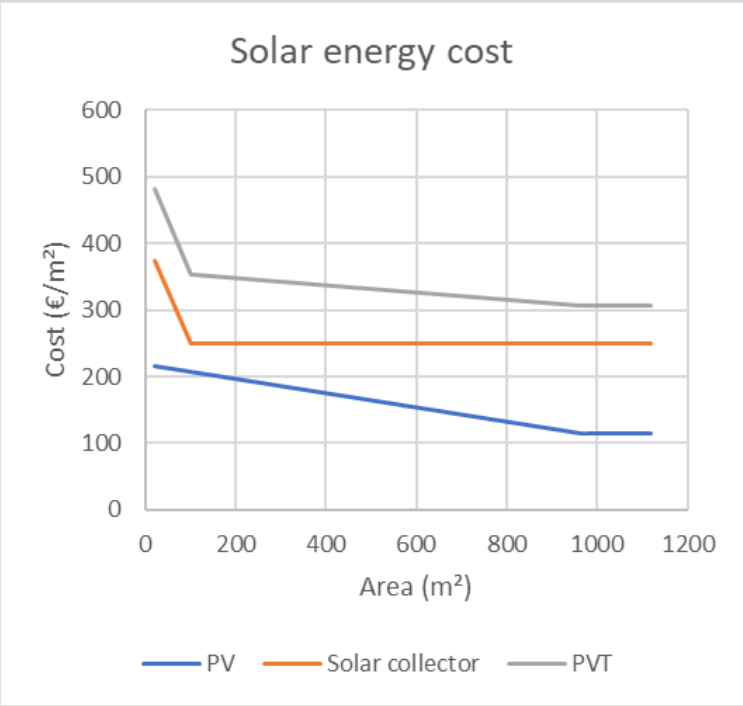

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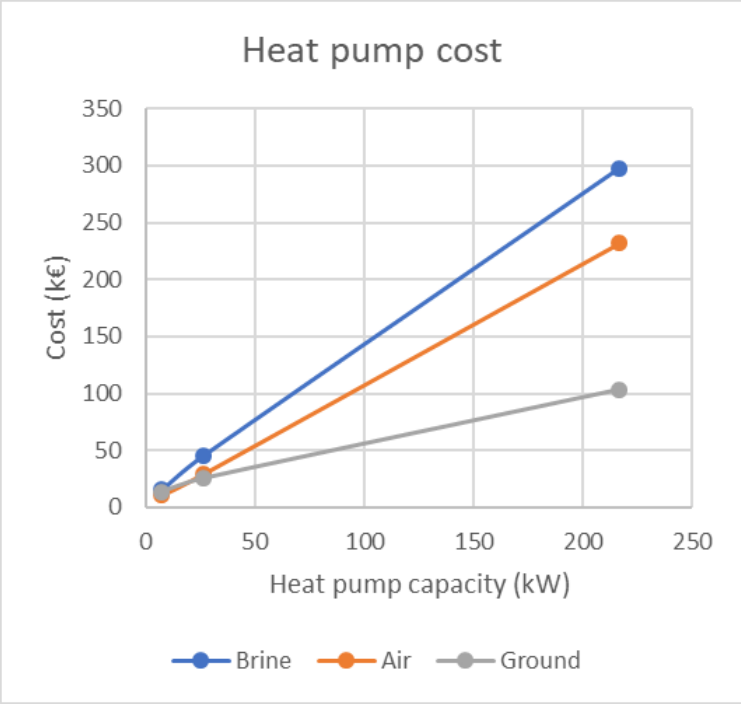

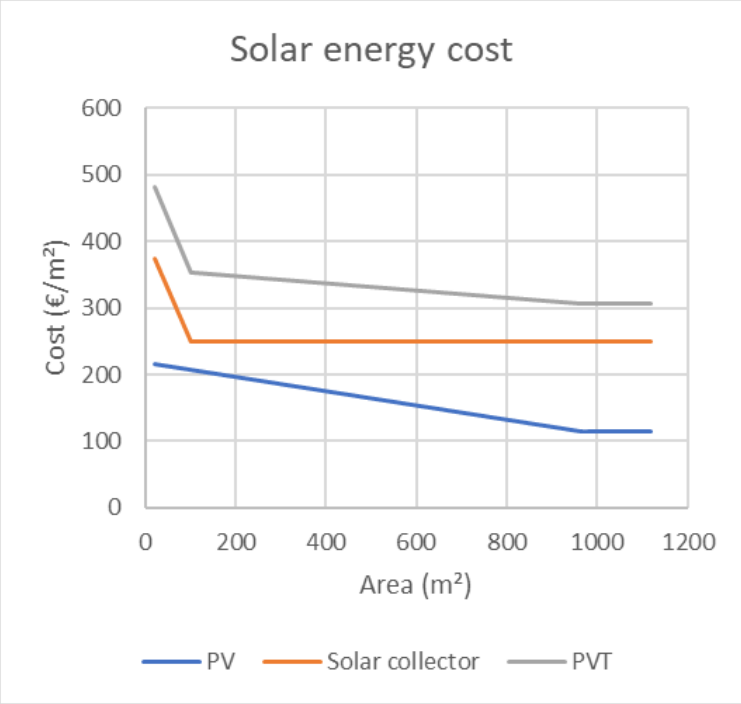

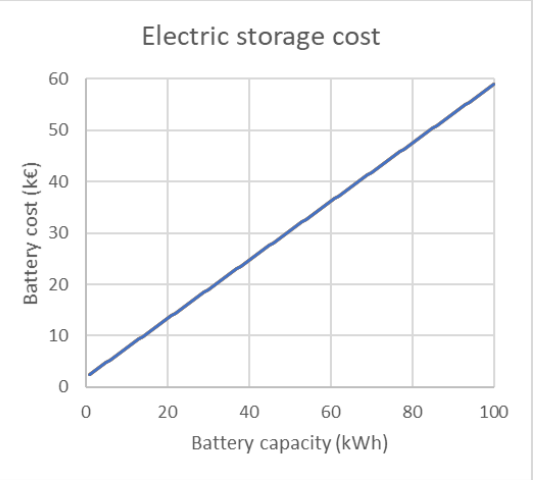

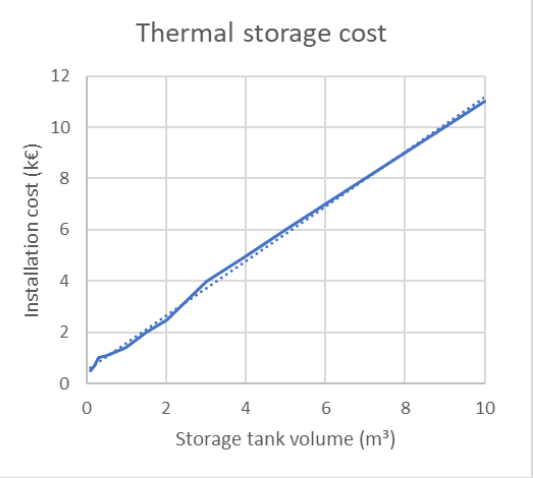

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VARKENSCAMPUS (BELGIUM)

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VARKENSCAMPUS

- Ghent, Belgium
- ~ 1000 pigs
  - 110 sows
  - 336 piglets
  - 463 fattening pigs

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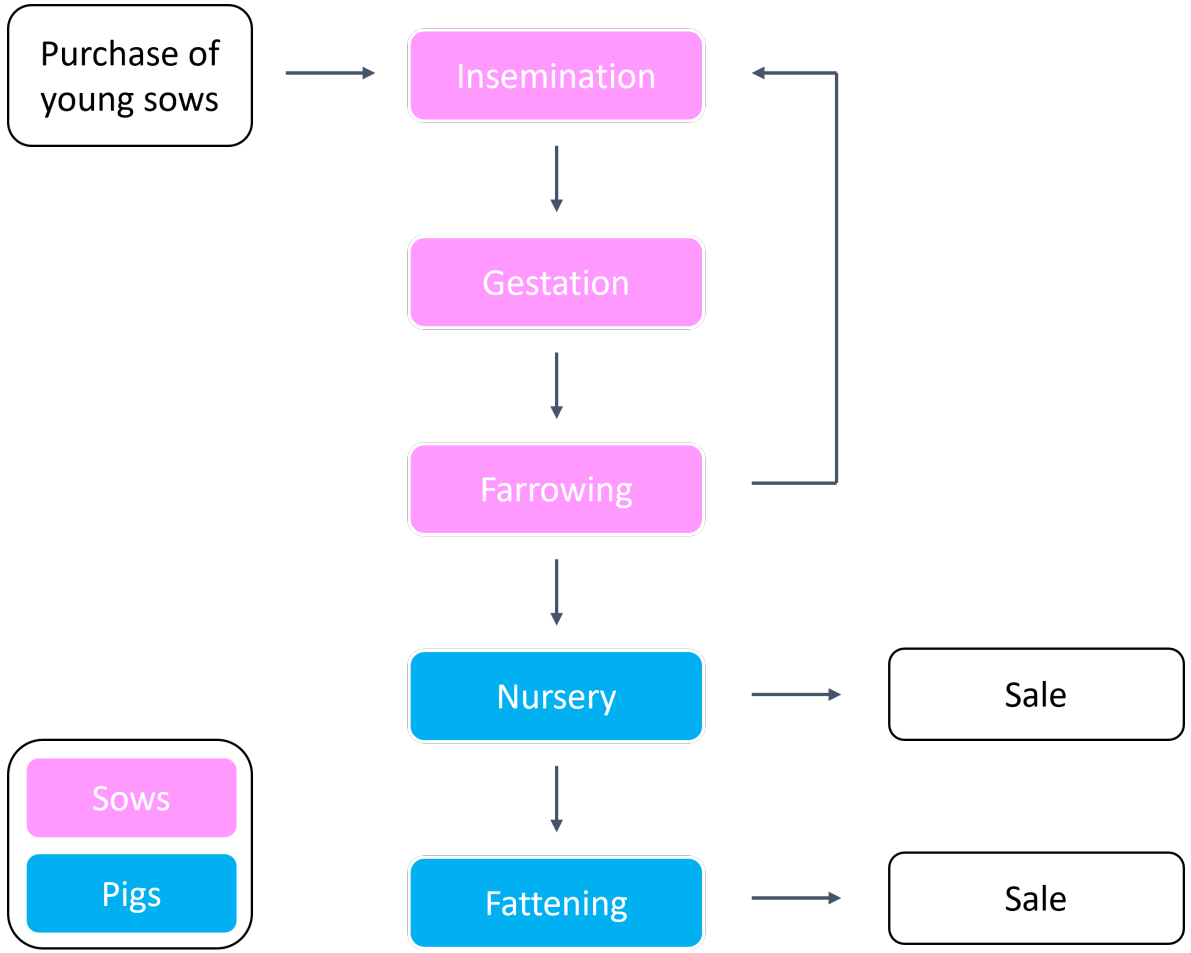
VARKENSCAMPUS

- Ghent, Belgium
- ~ 1000 pigs
  - 110 sows
  - 336 piglets
  - 463 fattening pigs
- Semi-closed-cycle farm



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TYPICAL ENERGY CONSUMPTION

- Heating
  - Natural gas (220 MWh a year)
  - Fuel oil (950 l a year)
- Electricity (115 MWh a year)

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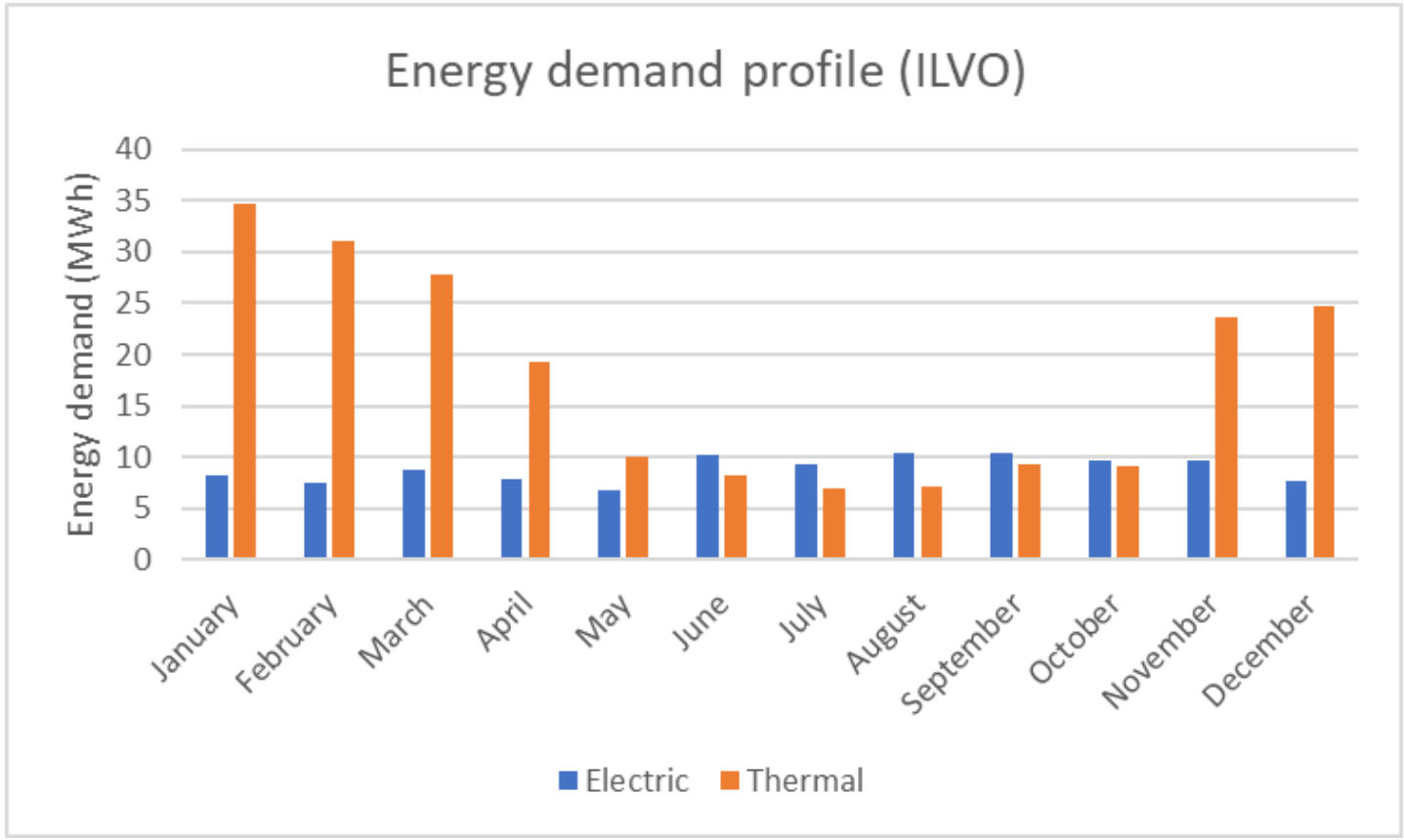

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SIMULATION PARAMETERS

- Input parameters
  - Energy demand profile for reference barn

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SIMULATION PARAMETERS

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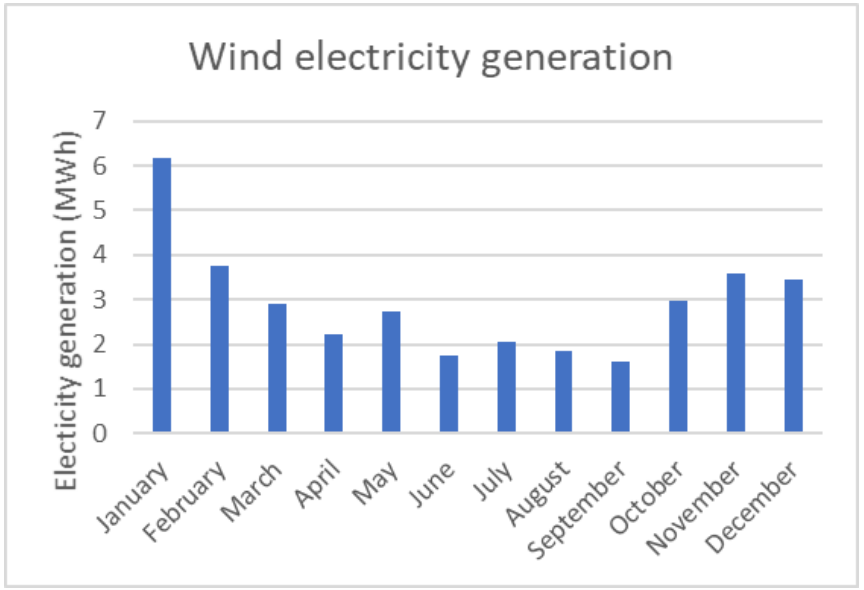
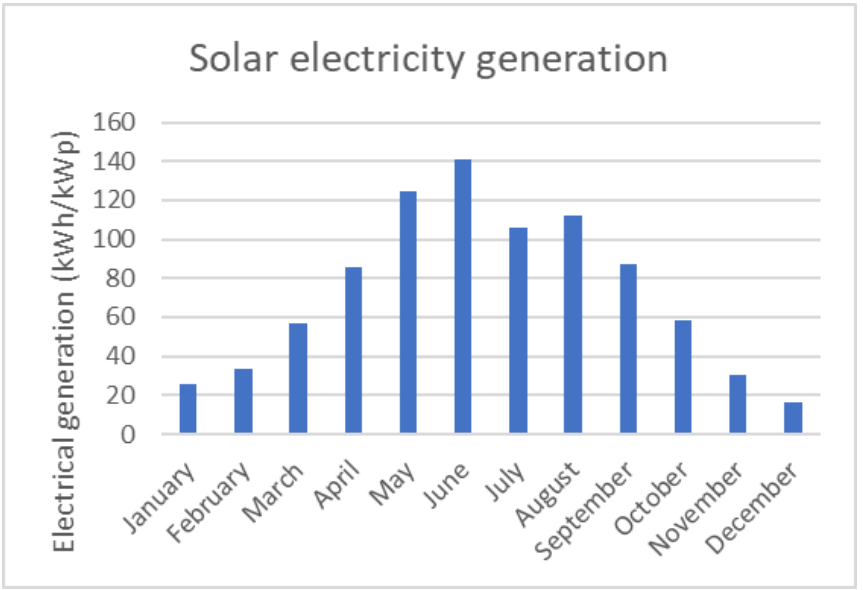
  - Local weather data





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SIMULATION PARAMETERS

- Input parameters
  - Energy demand profile for reference barn
  - Local weather data
- Base parameters
  - Timestep
  - Current energy costs
  - Lifetimes and maintenance costs
  - Machine properties

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SIMULATION PARAMETERS

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  - Machine properties

Parameter	Unit	Value
Simulation time step	hour	1
Simulated period	hour	8760
Electricity cost	€/kWh	0.28
Electricity injection fee	€/kWh	0.08
Gas cost	€/kWh	0.1
GHG emissions elec. grid	kg/kWh	0.22
GHG emissions gas grid	kg/kWh	0.24
LCC period	year	20
LCC discount rate	%	6
Boiler efficiency	%	95
Low temperature heating	°C	40
High temperature heating	°C	60
Low temp. nom. COP	-	5
High temp. nom. COP	-	3.5
COP nominal temperature	°C	17
Initial battery charge	kWh	0
Initial thermal storage temp.	°C	40
Max. thermal storage temp.	°C	90
Boiler life span	year	15
Heat pump life span	year	20
PV panels life span	year	25
Solar collectors life span	year	20
PVT panels life span	year	20
Wind turbine life span	year	20
Electrical battery life span	year	8
Thermal storage tank life span	year	20

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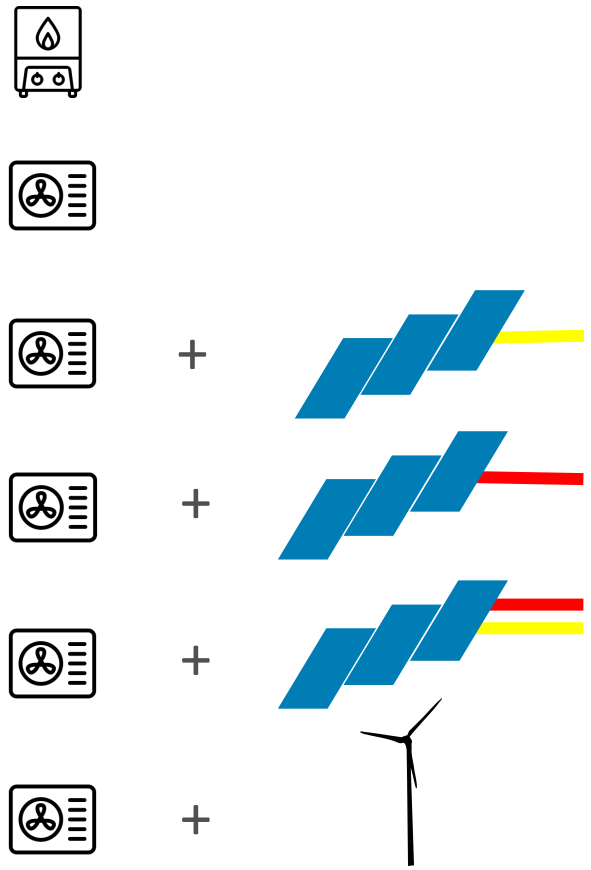
SOME WARM-UP SCENARIOS

- Scenario 1 (original)
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6



Electricity flow
Heat flow

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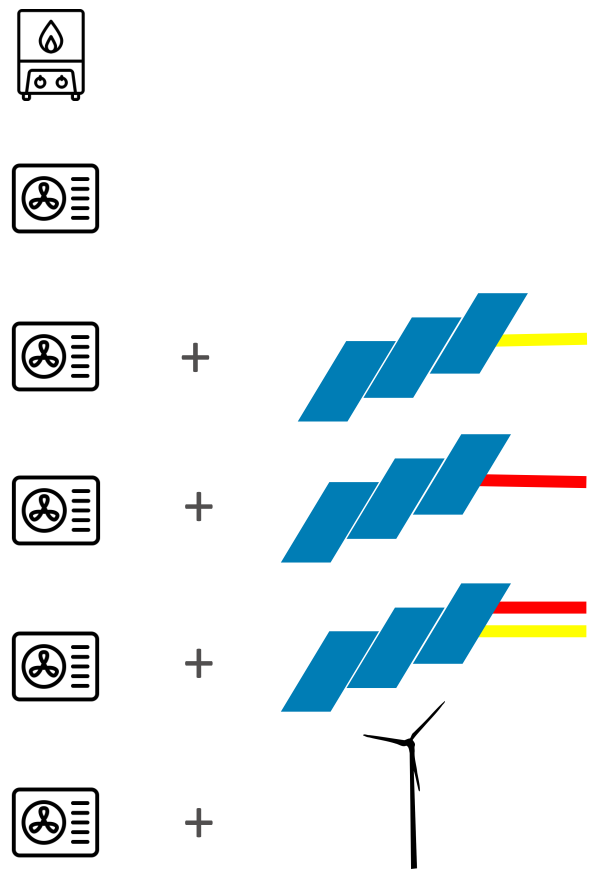

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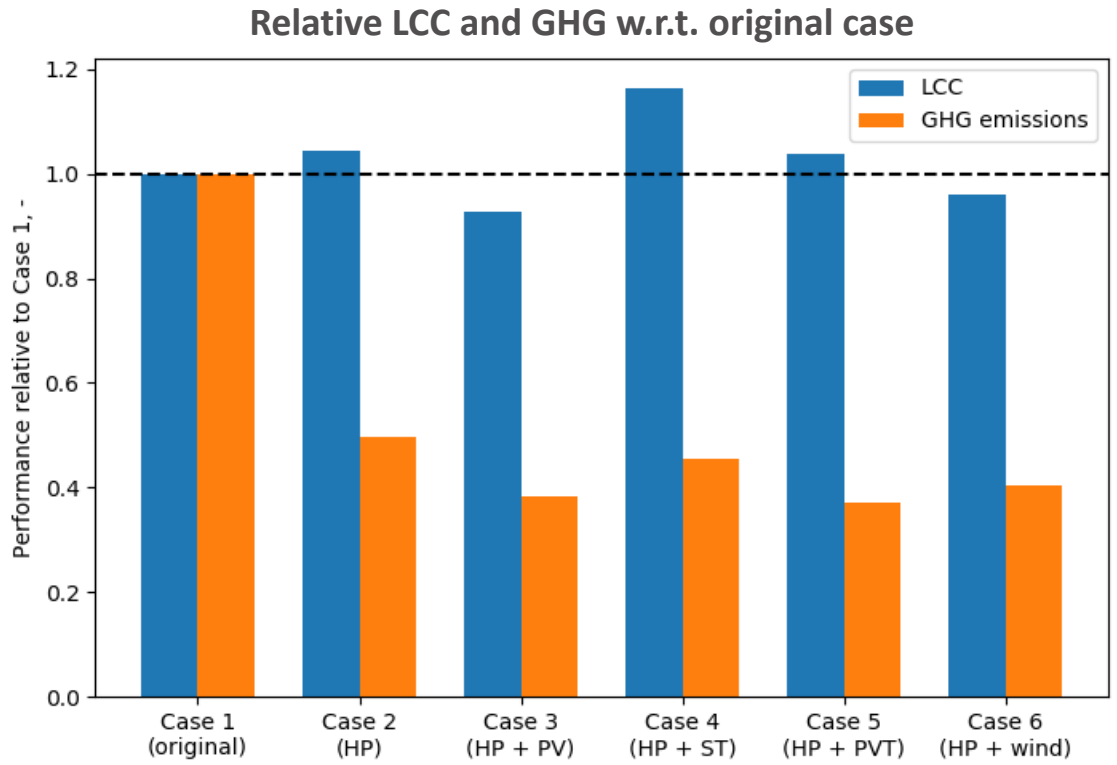

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RES EXPLORATION

- Design space exploration

Parameter	Possible values	Count
Heating system	• Gas boiler (60 kW) • High temperature heat pump (60 kW) • High temperature heat pump (55 kW) + low temperature heat pump (15 kW)	3
PV panel area (m²)	0, 10, 50, 100, 500, 1000, 2500, 5000	8
Solar collector area (m²)	0, 10, 50, 100, 500, 1000, 2500, 5000	8
PVT panel area (m²)	0, 10, 50, 100, 500, 1000, 2500, 5000	8
Battery capacity (kWh)	0, 10, 20, 50, 100, 200	6
Thermal storage volume (l)	0, 250, 500, 1000, 2500, 5000	6
Wind turbine nominal power (kW)	0, 15, 30	3

- All 165 888 possible combinations simulated

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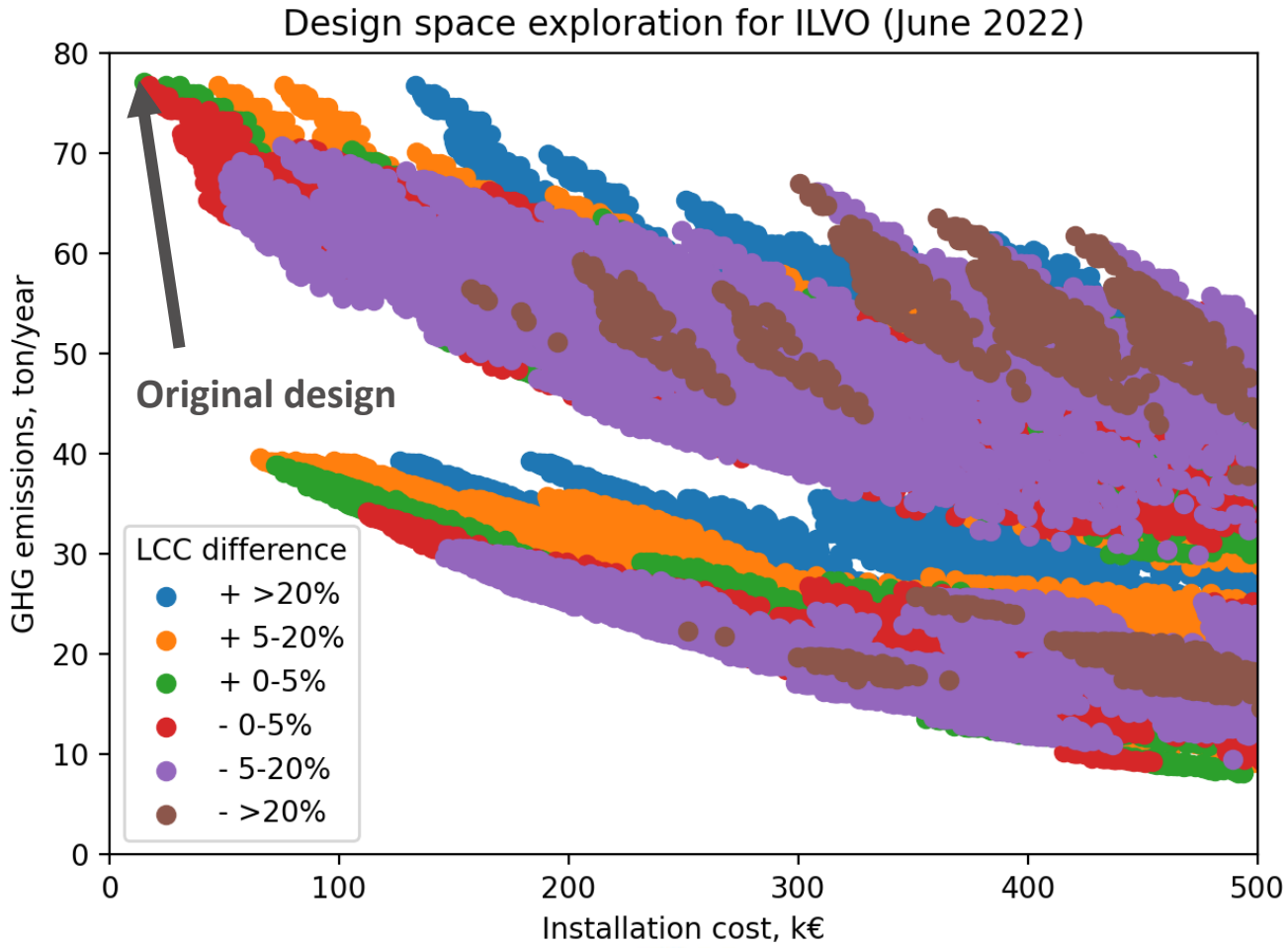
DESIGN SPACE EVALUATION



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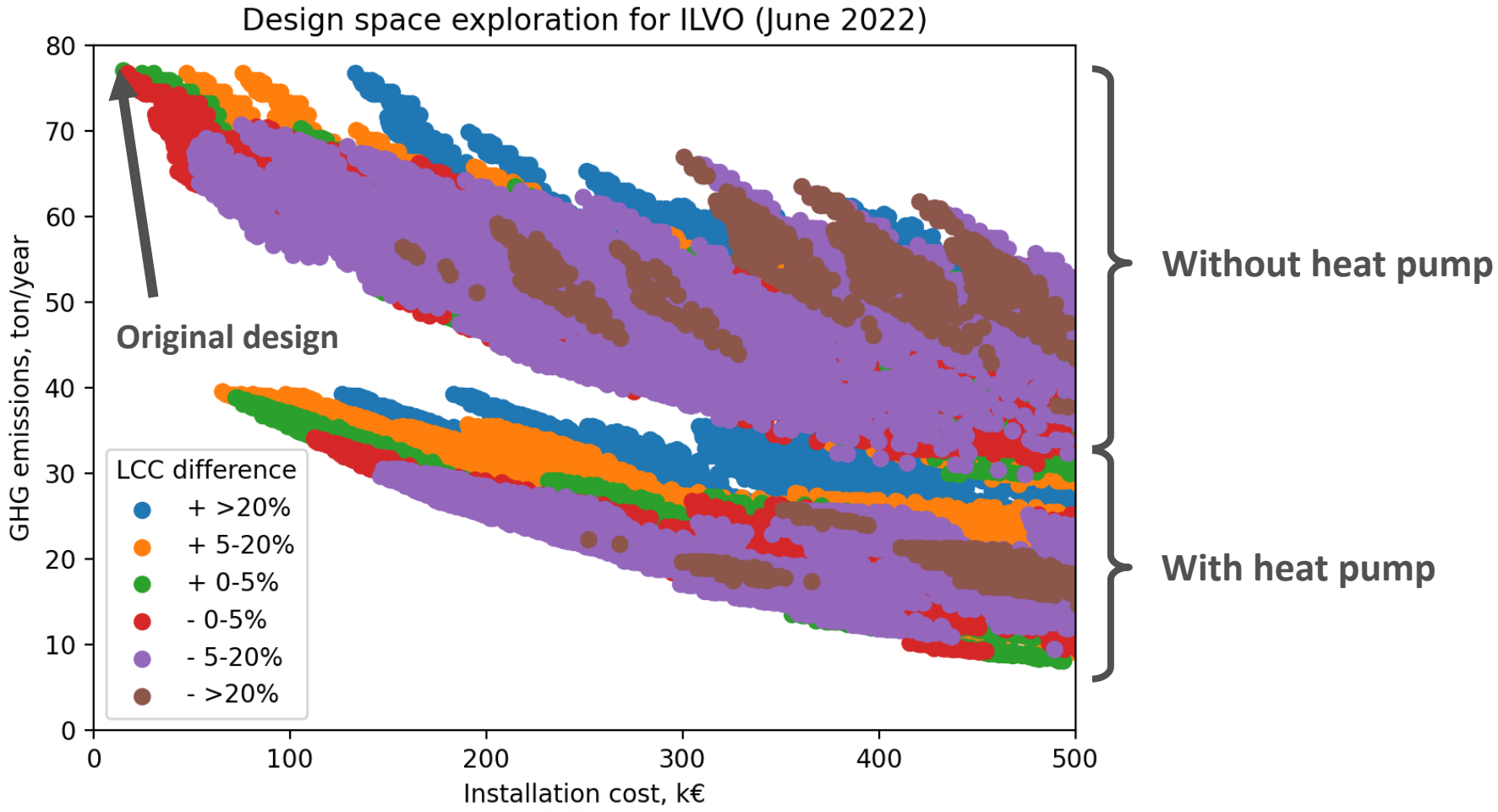

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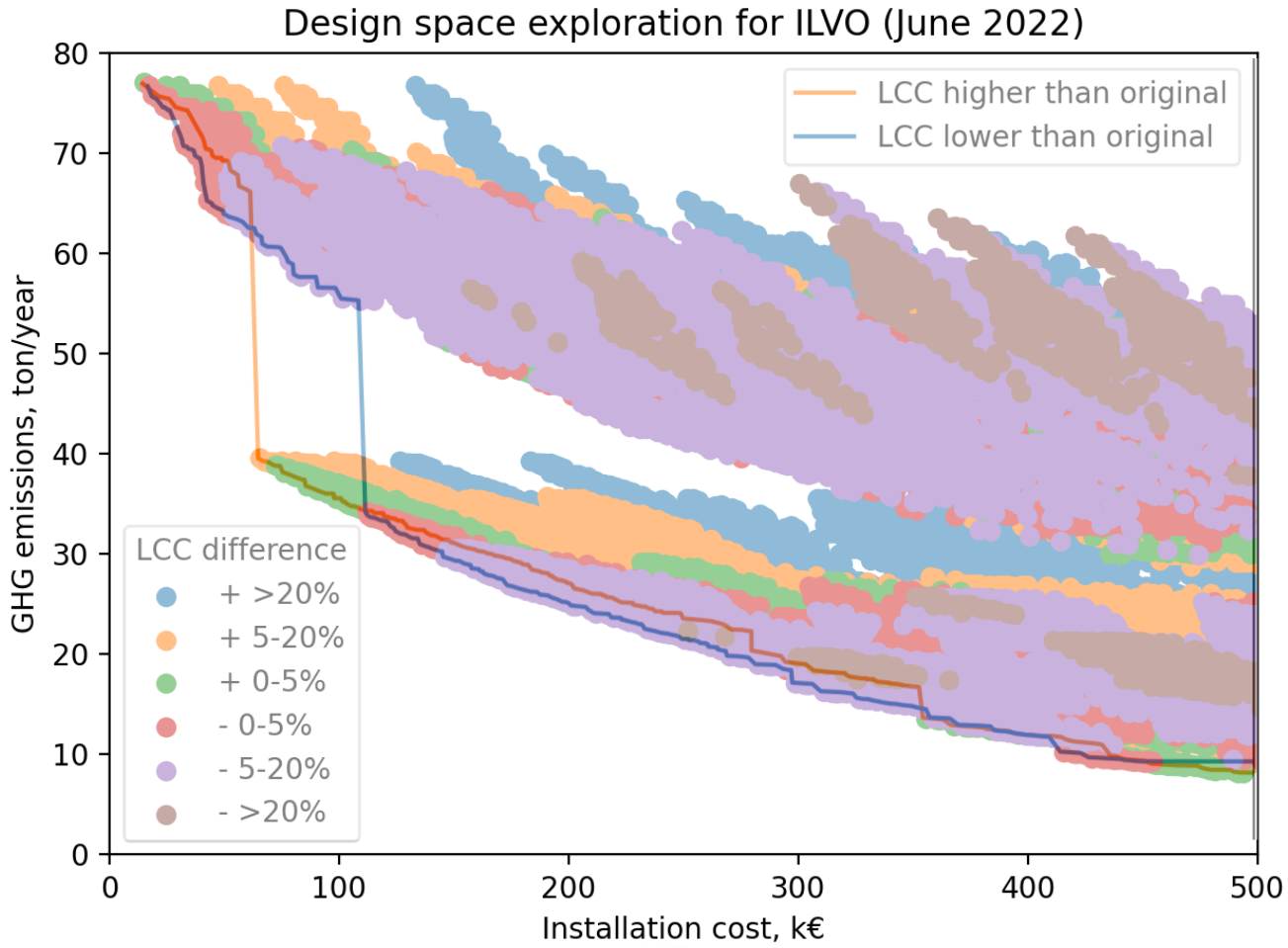
PARETO OPTIMIZATION



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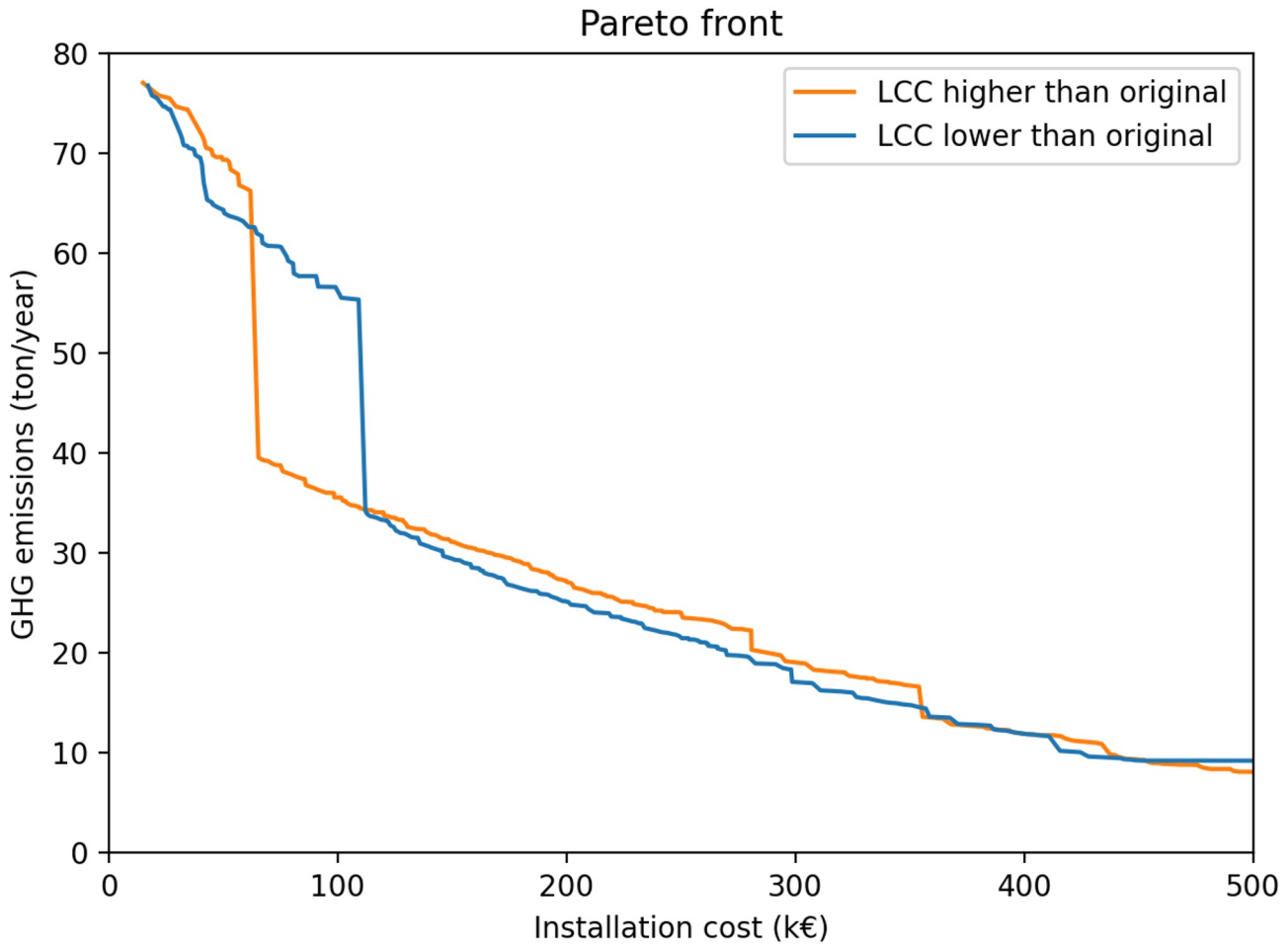
PARETO OPTIMIZATION



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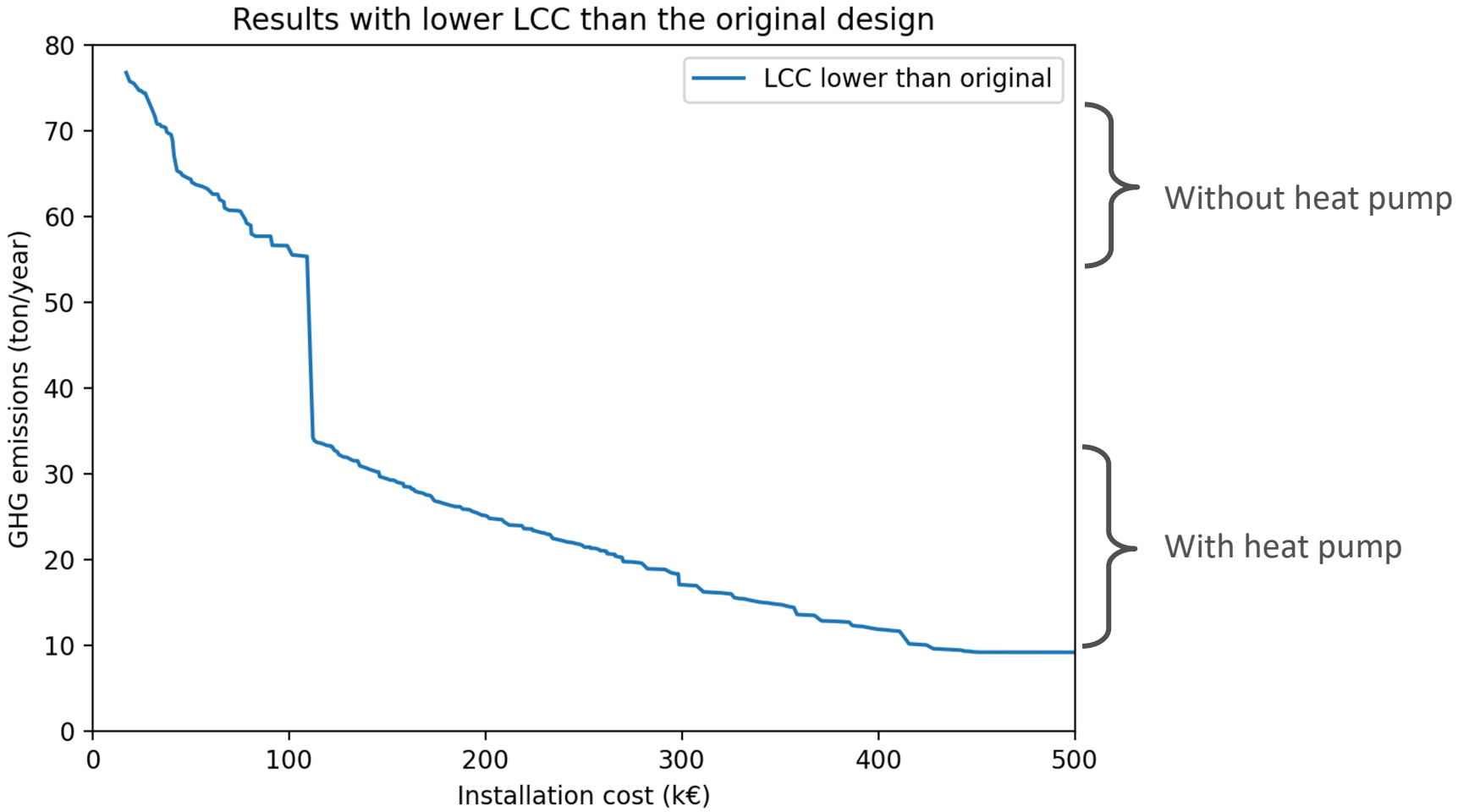
OPTIMIZED RES SYSTEM DESIGN



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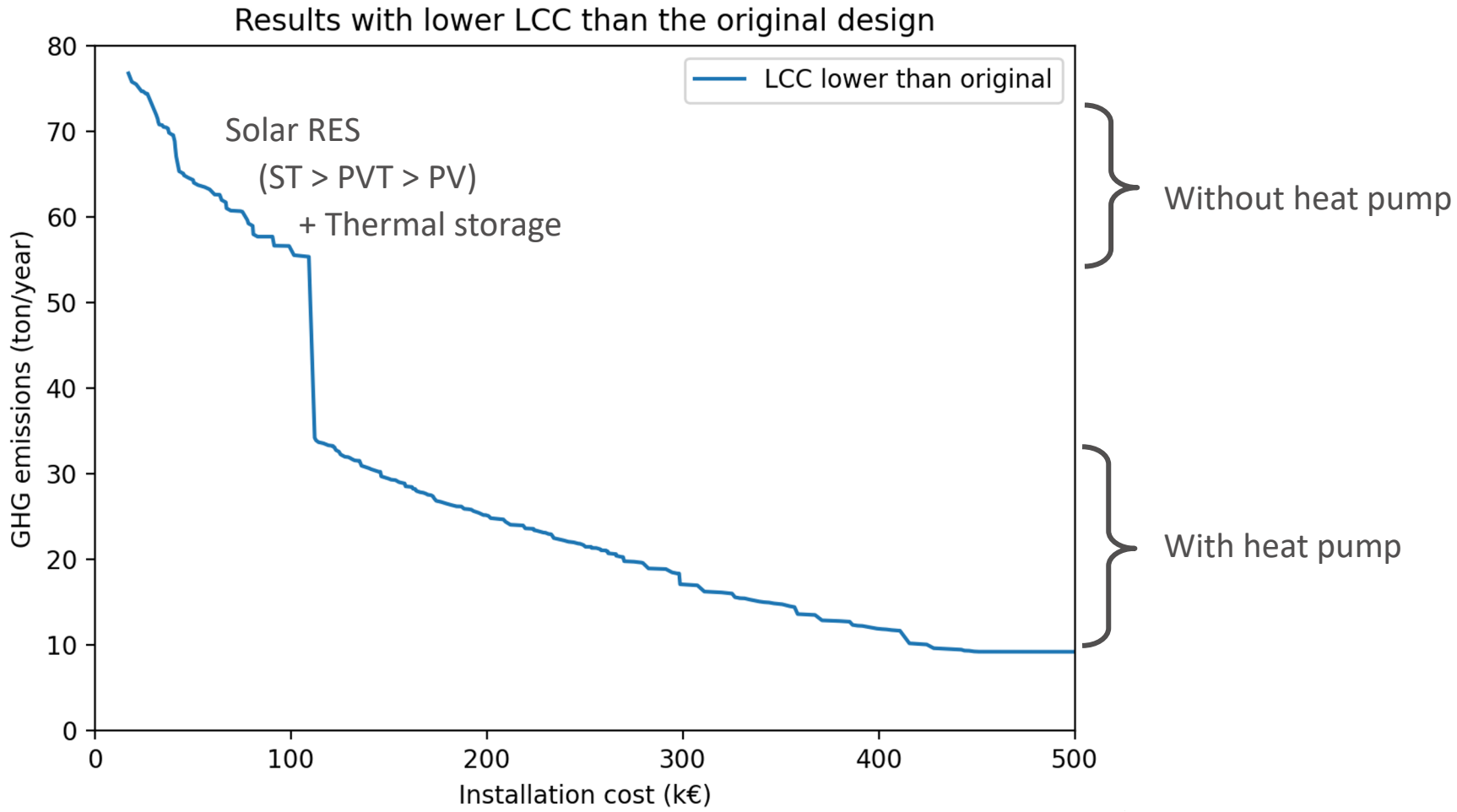

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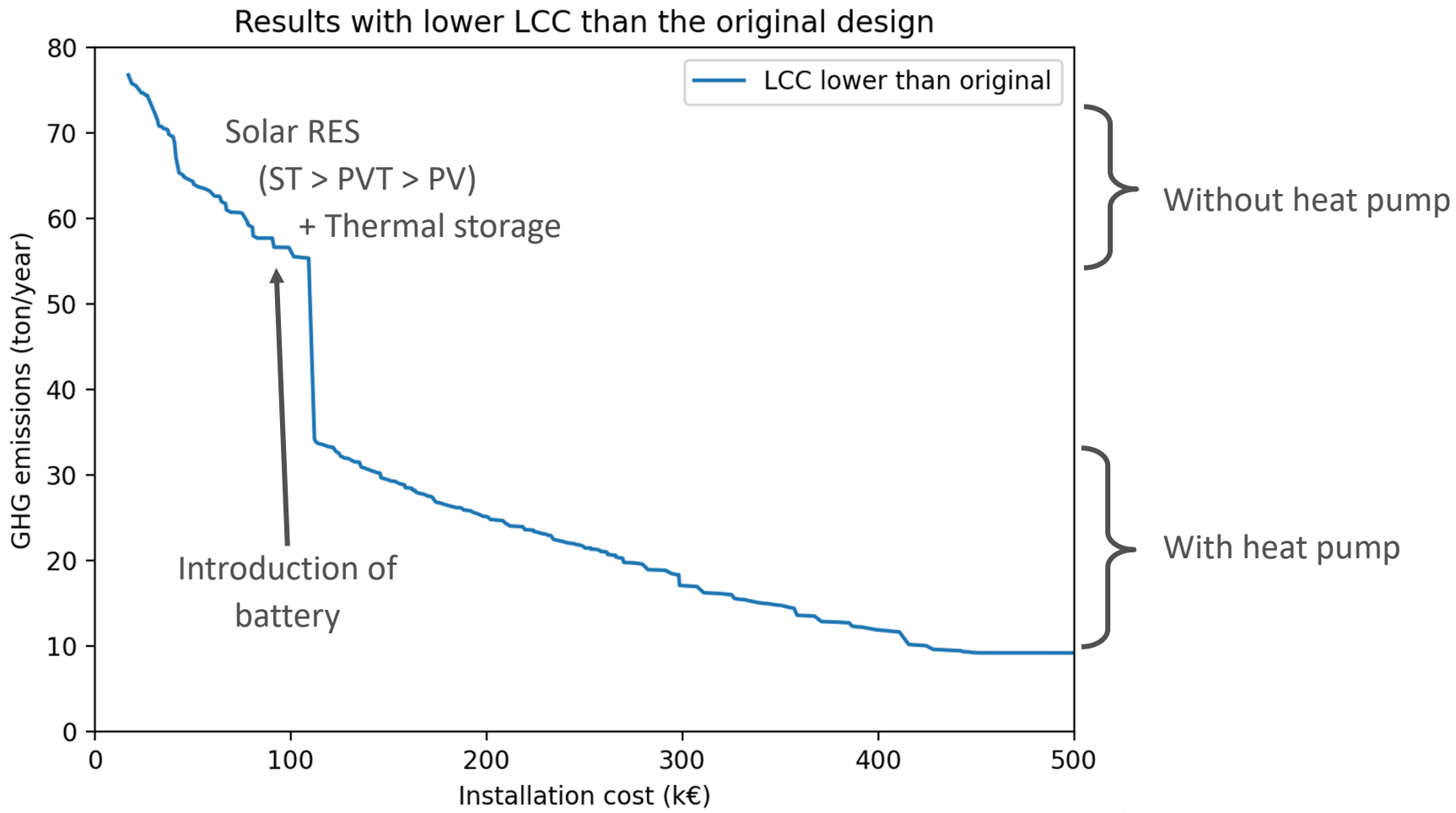
OPTIMIZED RES SYSTEM DESIGN



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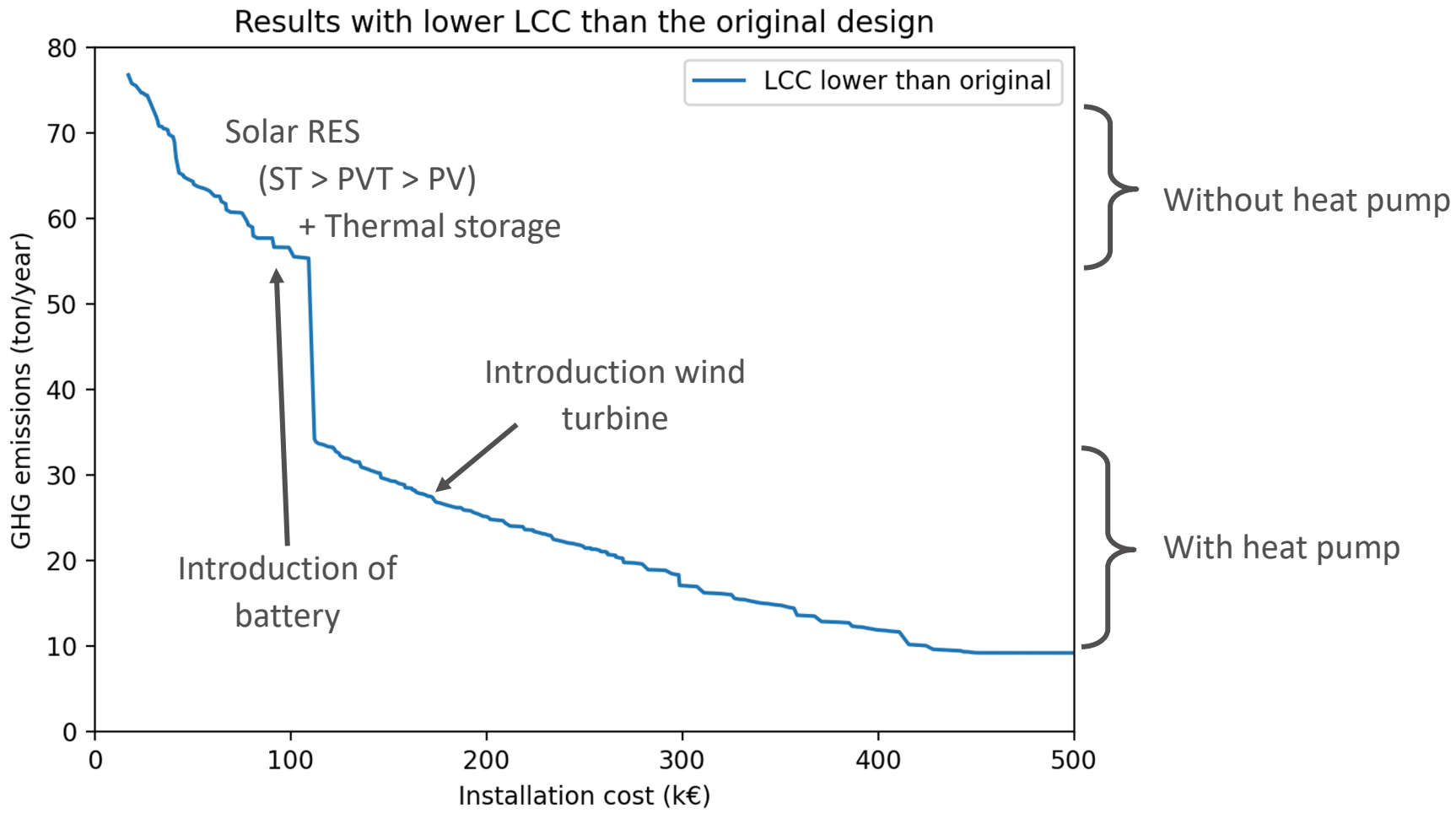

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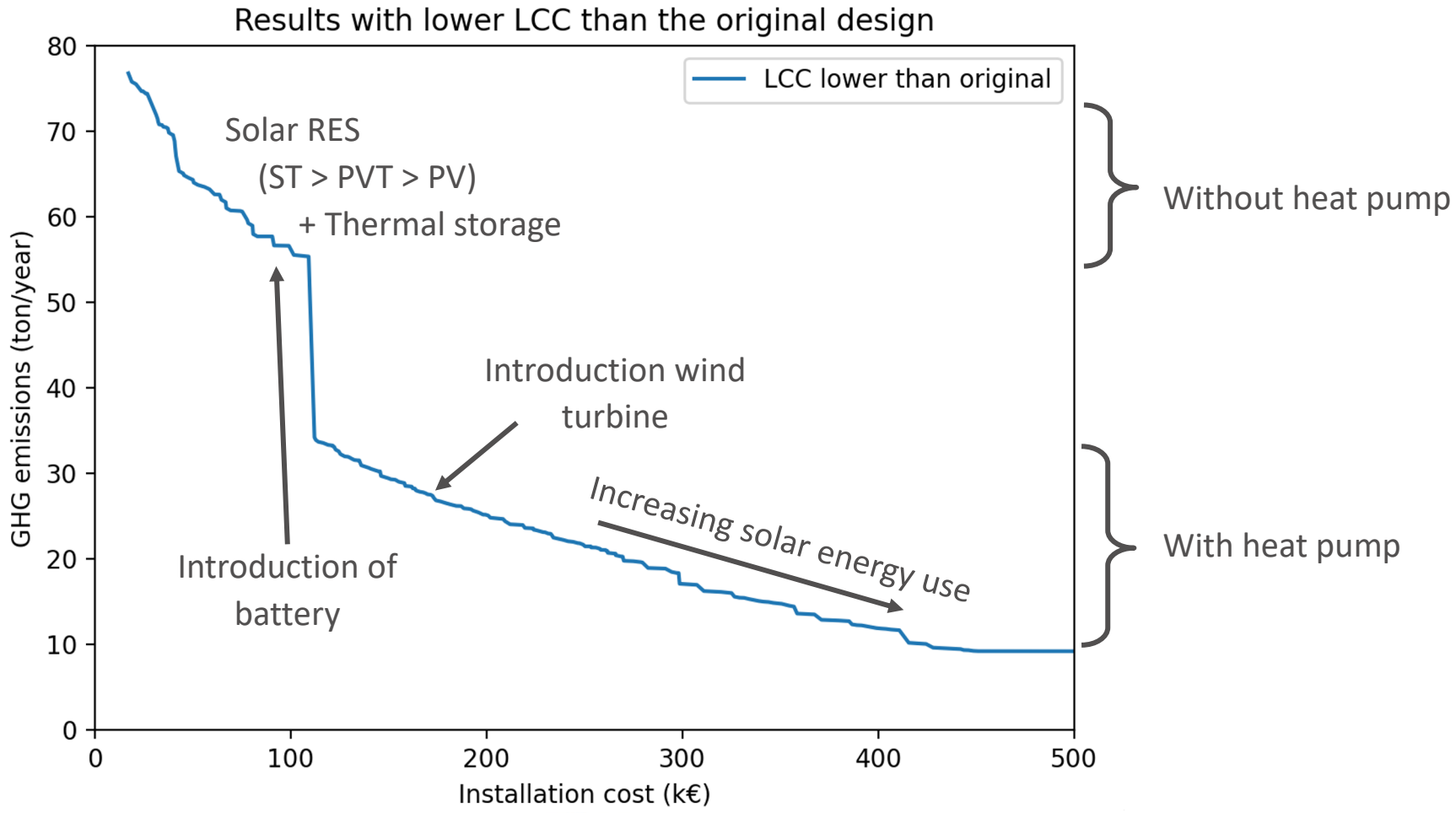

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CONCLUSION

- Potential to reduce greenhouse gas emissions
- Switch to heat pump
- Optimal use of roof area
  - No heat pump: thermal solar collectors
  - With heat pump: PV panels
- Solar energy > small wind turbine
- Thermal storage > electrical storage

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VDI Wissensforum

Thank you!

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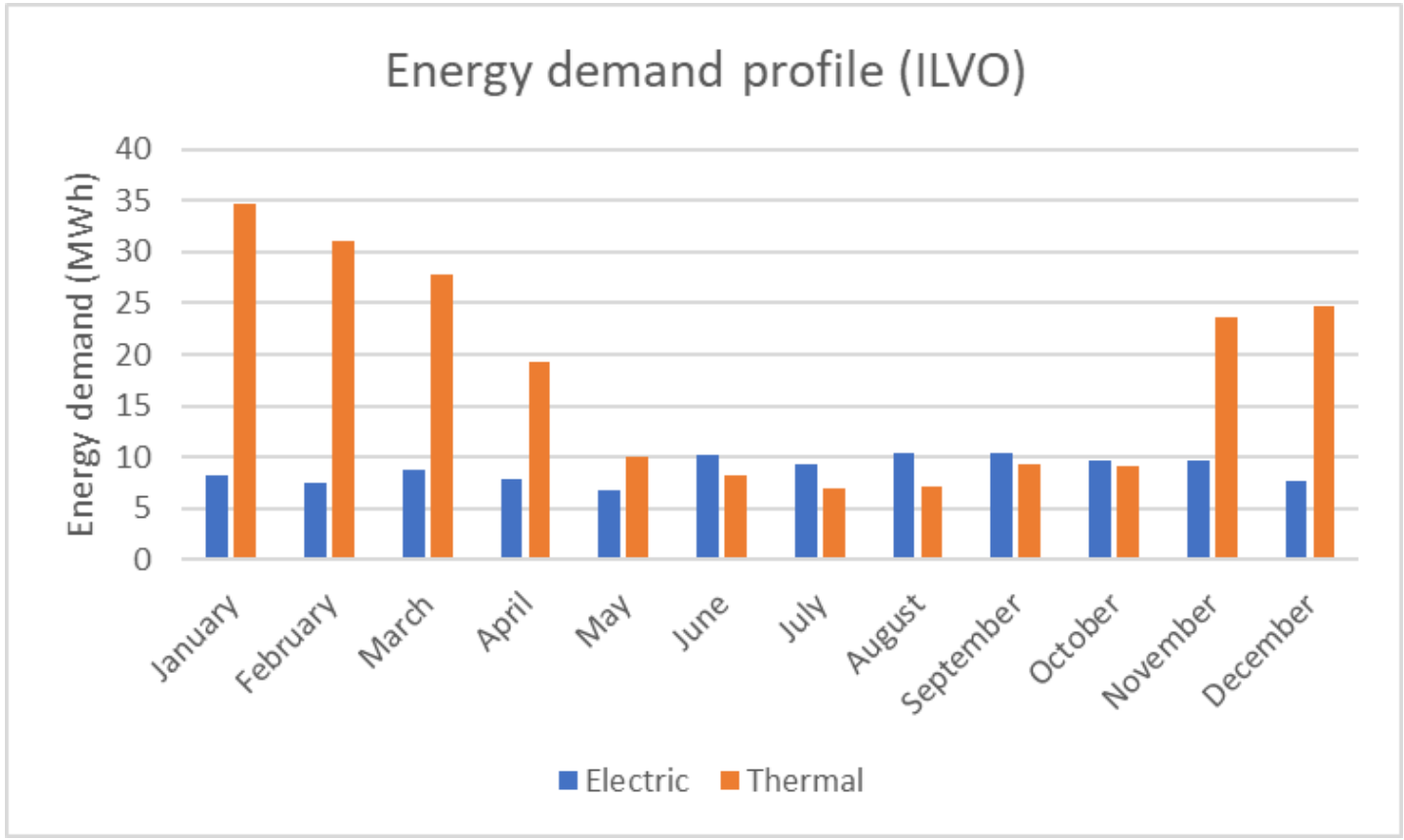
NUMBERS OF CURRENT INSTALLATION

- Initial cost: €15 000 (only gas boiler)
- LCC over 20 years: € 632 782,6
- Yearly energy cost: € 51 055
  - Gas: € 21 204
  - Electricity: € 29 851
- Yearly GHG emissions: 77,1 ton
  - Grid electricity: 23,5 ton
  - Fuel combustion: 53,6 ton



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