Sector Coupling of a Local Energy System

Influence of Location Dependent Parameters

Frida Revheim, Daniel Schwabeneder, Georg Lettner

TU Wien ESEA
revheim@eeg.tuwien.ac.at

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Introduction

- Introduction and motivation
- Methodology
  - Model development
  - Use cases
- Preliminary results
- Further work

Idea and motivation

- Sector coupling could be part of a solution to reach GHG emission targets
  - Green hydrogen and green heat
  - Curtailment reduction

- Potential benefits of sector coupling will depend on system location and location-specific variables
  - Electricity generation
  - Energy demands
  - Available fuel options

- Comparative analysis is performed to evaluate the influence of location-dependent parameters on system operation and profitability

- **Two key motivational factors:**
  - Ensure continued implementation and operation of RES
  - Reduce GHG emissions

Investigated KPIs

- Investigated KPIs:
  - Profitability
  - Degree of utilization of implemented technologies
  - GHG emission reduction potential
  - Renewable energy self-reliance
  - External energy purchase
  - Curtailment reduction

Methodology – model development

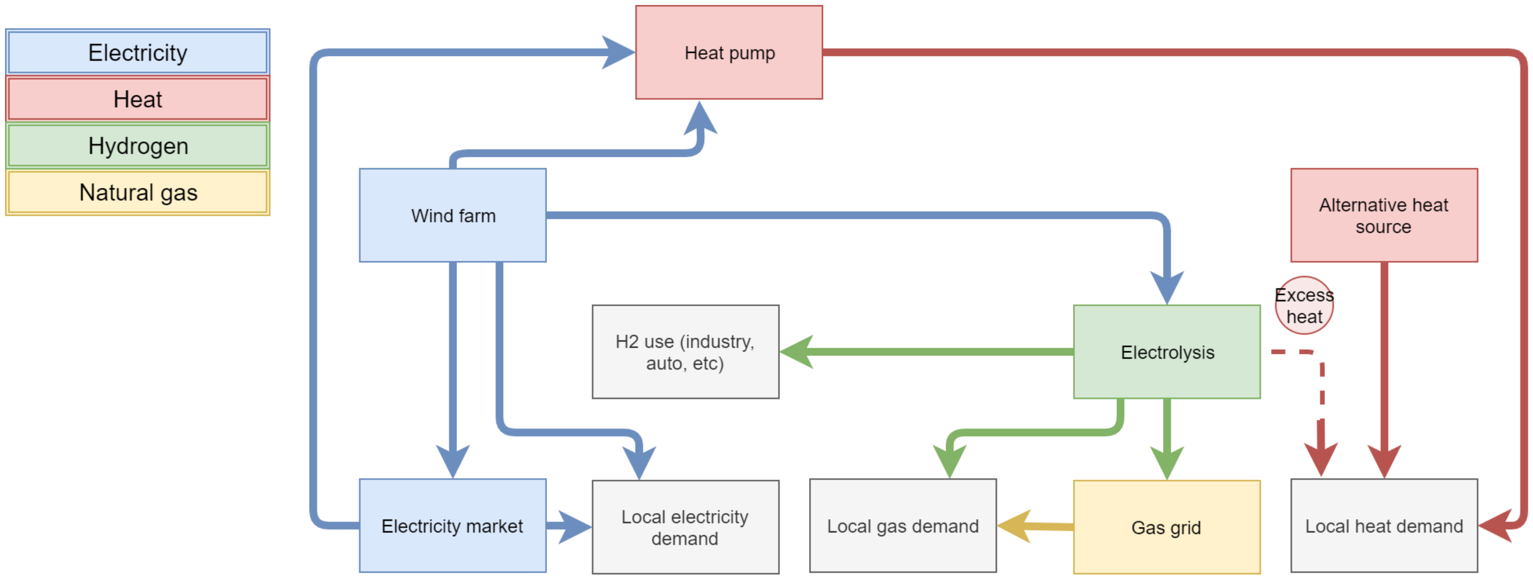
- Optimization model of sector coupled system developed in Julia
- Operational model, not considering investment costs
- Objective: optimize system operation to maximize profit, while meeting energy demands and following constraints at all times

$$
\begin{aligned}
&max \sum_{t \in T} (P_t^{el} \cdot El_t^{sell} + P_t^{H2} \cdot H2_t^{Sell} + P_t^{NG} \cdot H2_t^{Sell,gasmarket} \\
&-C_t^{el} \cdot (El_t^{Buy,heatpump} + El_t^{Buy,demand}) - C_t^{NG} \cdot NG_t^{Buy} - C_t^{Heat} \cdot Heat_t^{Buy})
\end{aligned} \quad (1)
$$

- Revenues:
  - Selling electricity to the electricity market
  - Selling hydrogen to the gas market
  - Selling hydrogen to industry/mobility
- Costs:
  - Buying electricity to cover electricity demand
  - Buying electricity to feed into heat pump
  - Buying heat produced by alternative heat source to cover heat demand
  - Buying natural gas to cover gas demand

Methodology – model development

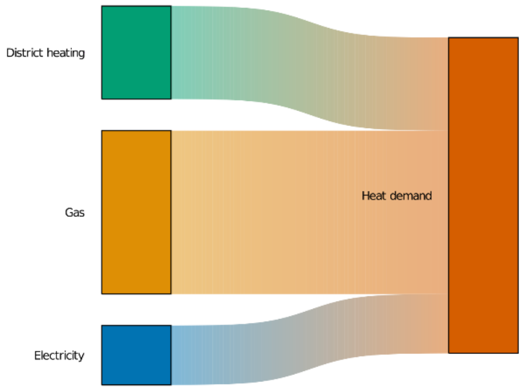
- Investigated system includes both P2H and P2G technology
- Three different use cases
  - Austria, Norway, Spain
- Location-dependent parameters as input for model
  - Electricity generation from wind farm
  - Local electricity, heat and gas demand
  - Electricity prices, gas prices, price for alternatively produced heat
  - Alternatives to green heat and the corresponding emissions
  - Electricity mix



Methodology – use cases

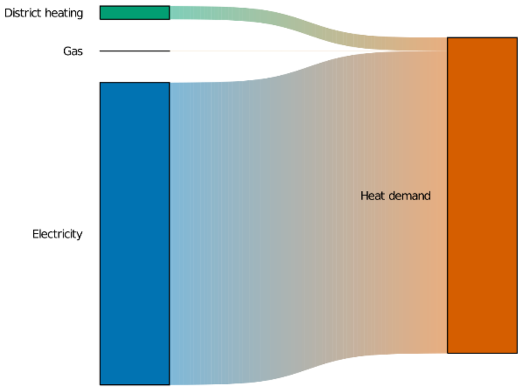
Austrian use case[1]:

- Neusiedl am See region
- 4290 households
- Wind farm with 32 MW installed capacity
- Majority of heat demand covered by gas



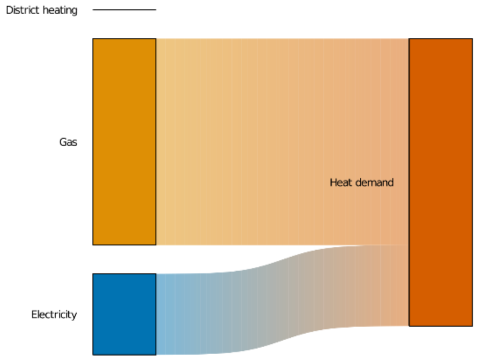
Norwegian use case[1]:

- Åfjord municipality
- 1961 households
- Wind farm with 57.5 MW installed capacity
- Majority of heat demand covered by electricity
- No gas demand considered



Spanish use case[1]:

- Municipalities of Isar,Las Quintanillas,Rabé de las Calzadasandand Estepar
- 1000 households
- Wind farm with 31.5 MW installed capacity
- Majority of heat demand covered by gas
- No district heating demand considered



Methodology – scenarios

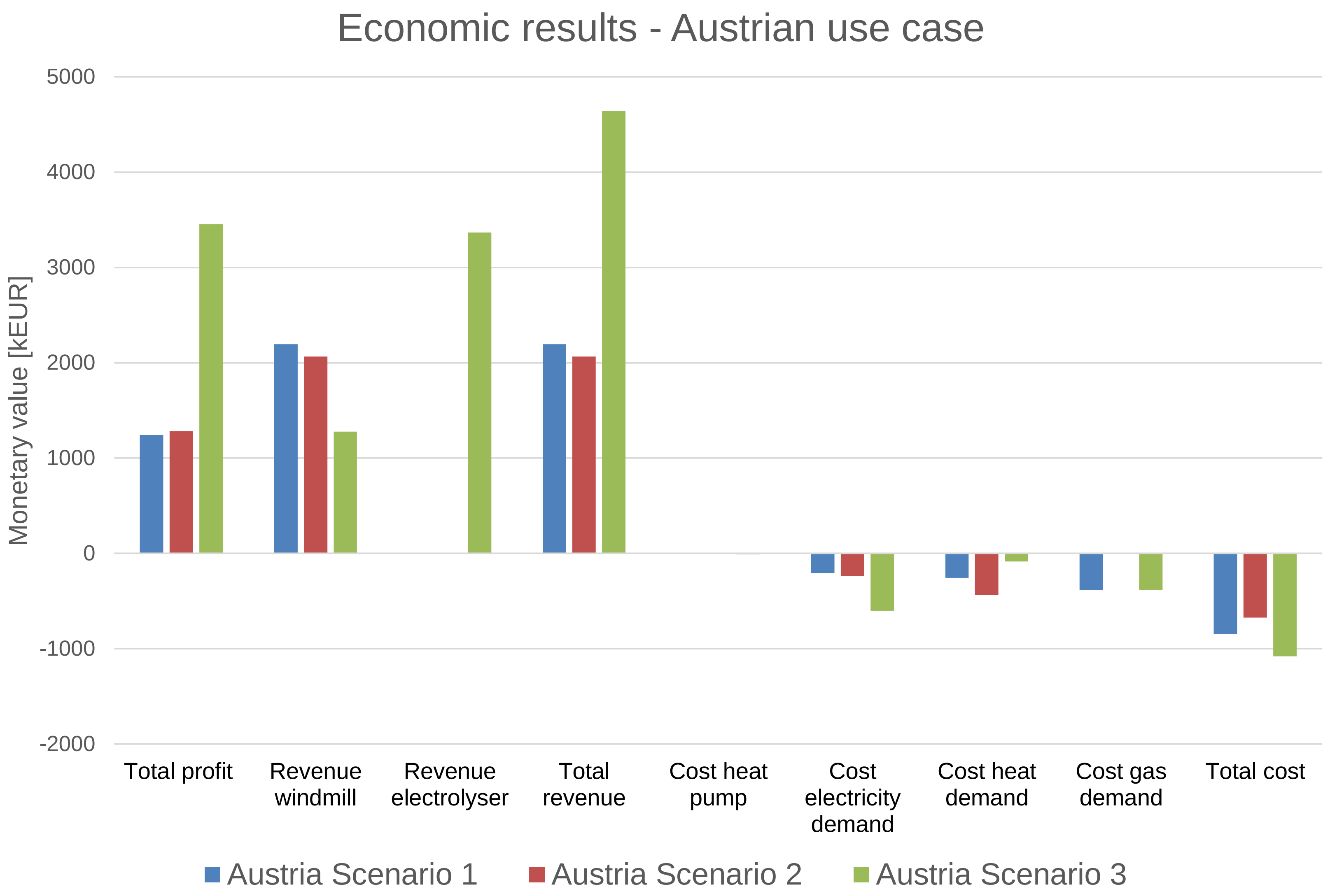
- Three scenarios investigated for each use case
  - Scenario 1
    - Electricity demand → electricity generated by wind farm and electricity bought from electricity market
    - Heat demand → heat bought from an alternative heat source
    - Gas demand → natural gas bought from the gas grid
  - Scenario 2
    - Electricity demand → electricity generated by wind farm and electricity bought from electricity market
    - Gas-using customers assumed connected to district heating grid
    - Heat pump scaled according to district heating demand
  - Scenario 3
    - Electricity demand → electricity generated by wind farm and electricity bought from electricity market
    - Gas-using customers assumed switching to green hydrogen
    - Heat pump scaled according to district heating demand
    - Electrolyzer scaled according to gas demand

Scenario 1
- Wind farm

Scenario 2
- Wind farm
- Heat pump

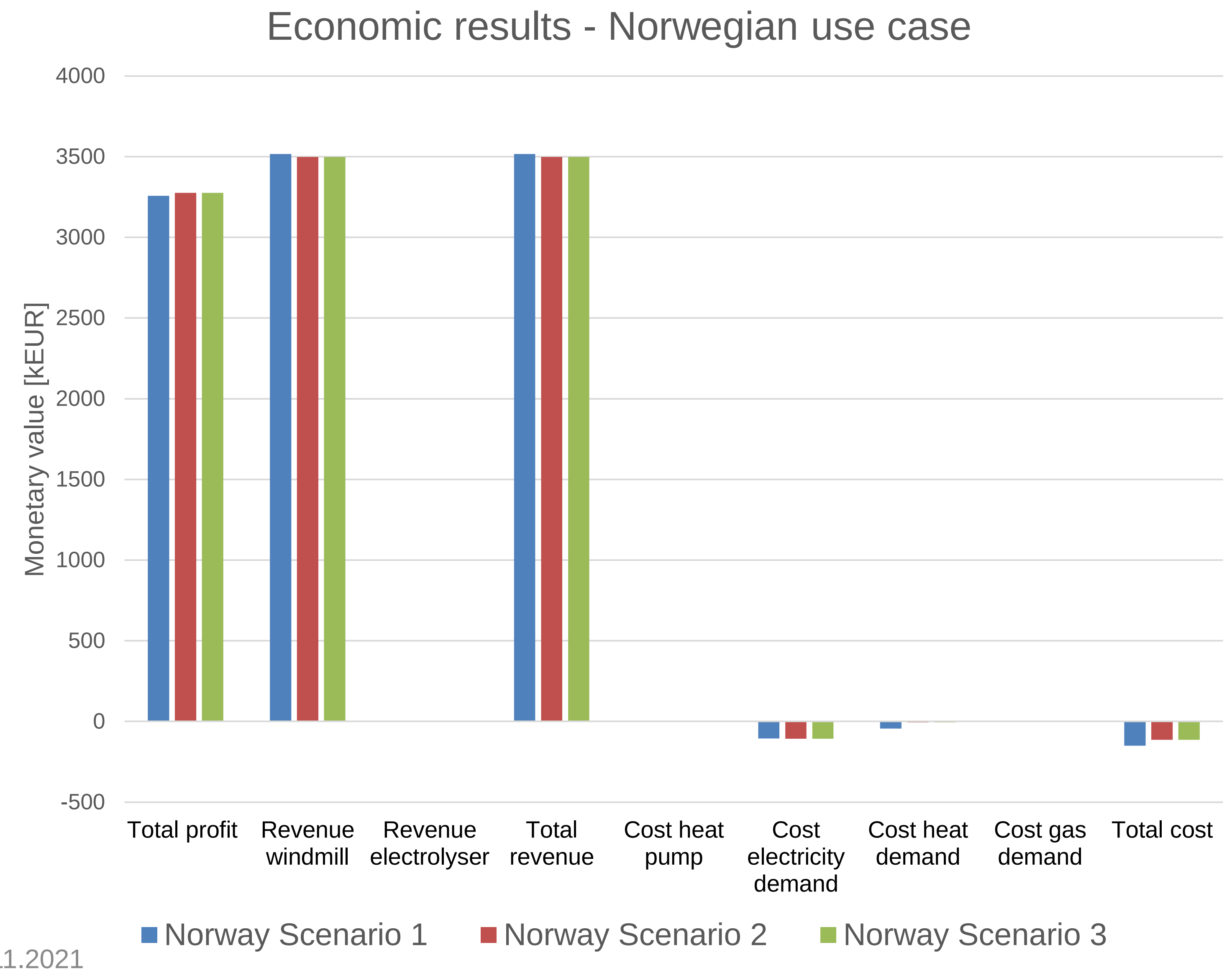
Scenario 3
- Wind farm
- Heat pump
- Electrolyzer

Results – economic, AT use case



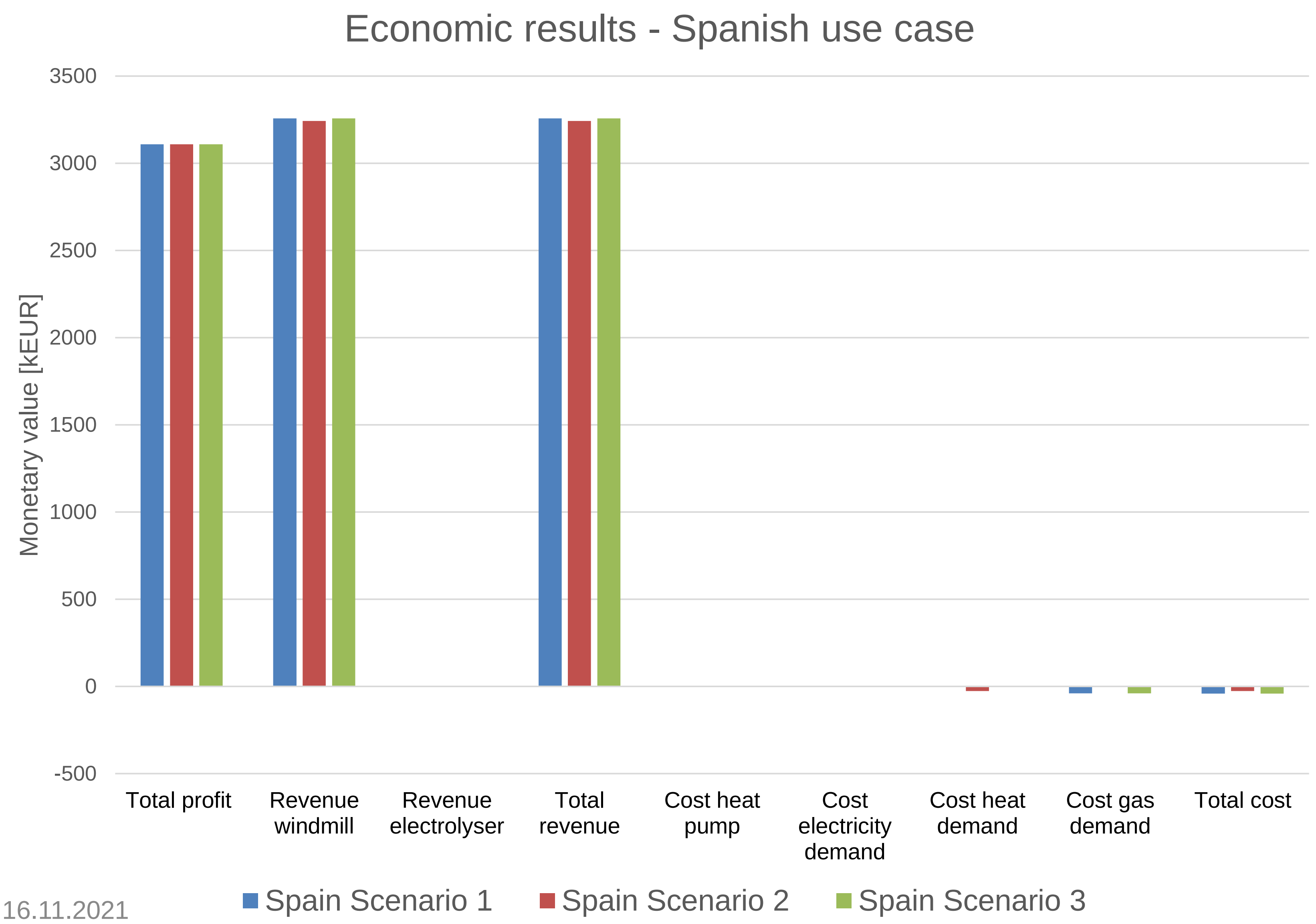
- System is profitable in all investigated scenarios
- Introduction of electrolyzer significantly influences profit
- Introduction of heat pump reduces costs related to covering the heat demand

Results – economic, NO use case



- System is profitable in all investigated scenarios
- Slight increase in profitability due to heat pump implementation
- No electrolyzer implemented (no gas demand)

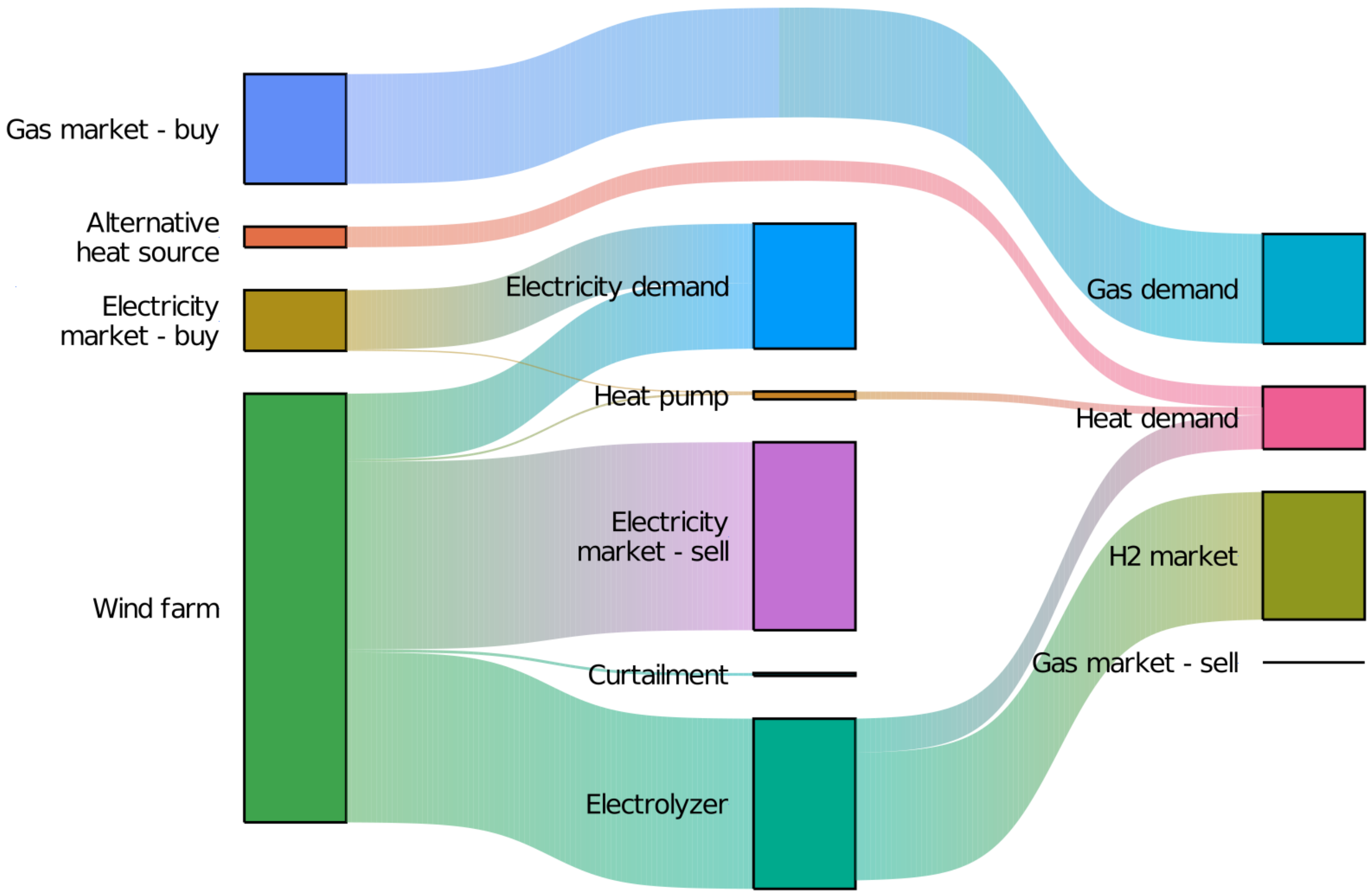
Results – economic, ES use case



- System is profitable in all investigated scenarios
- Slight increase in profitability due to heat pump implementation
- No heat pump implemented in scenario 3 (no district heating demand)

Utilization of implemented technologies to cover demands – Austria scenario 3

- Overview of technology utilization in Austrian use case – scenario 3
- Generated electricity is either sold, used to cover demand or fed into electrolyzer
- Gas demand fully met by bought natural gas

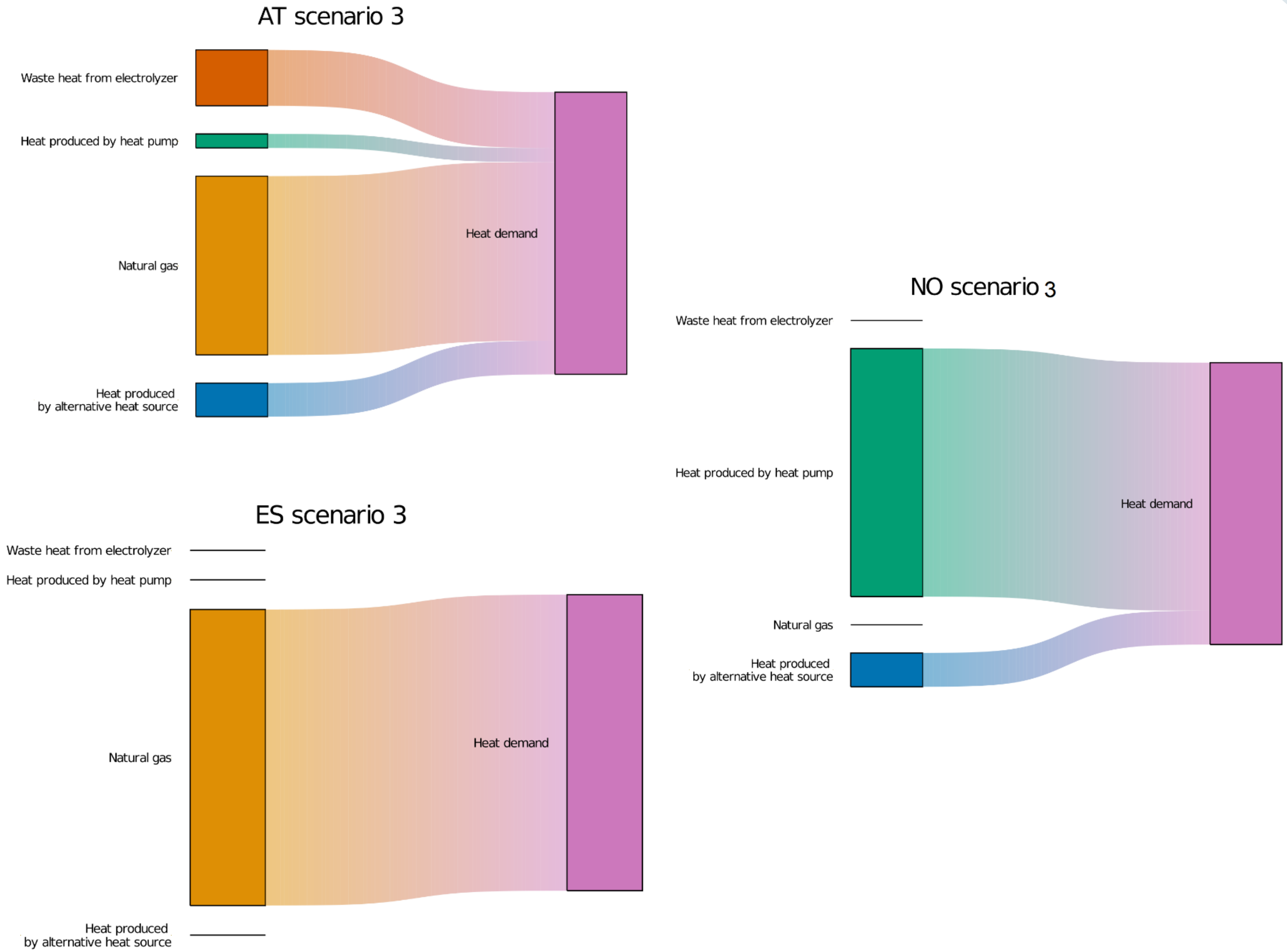


Utilization of implemented technology to cover heat demand

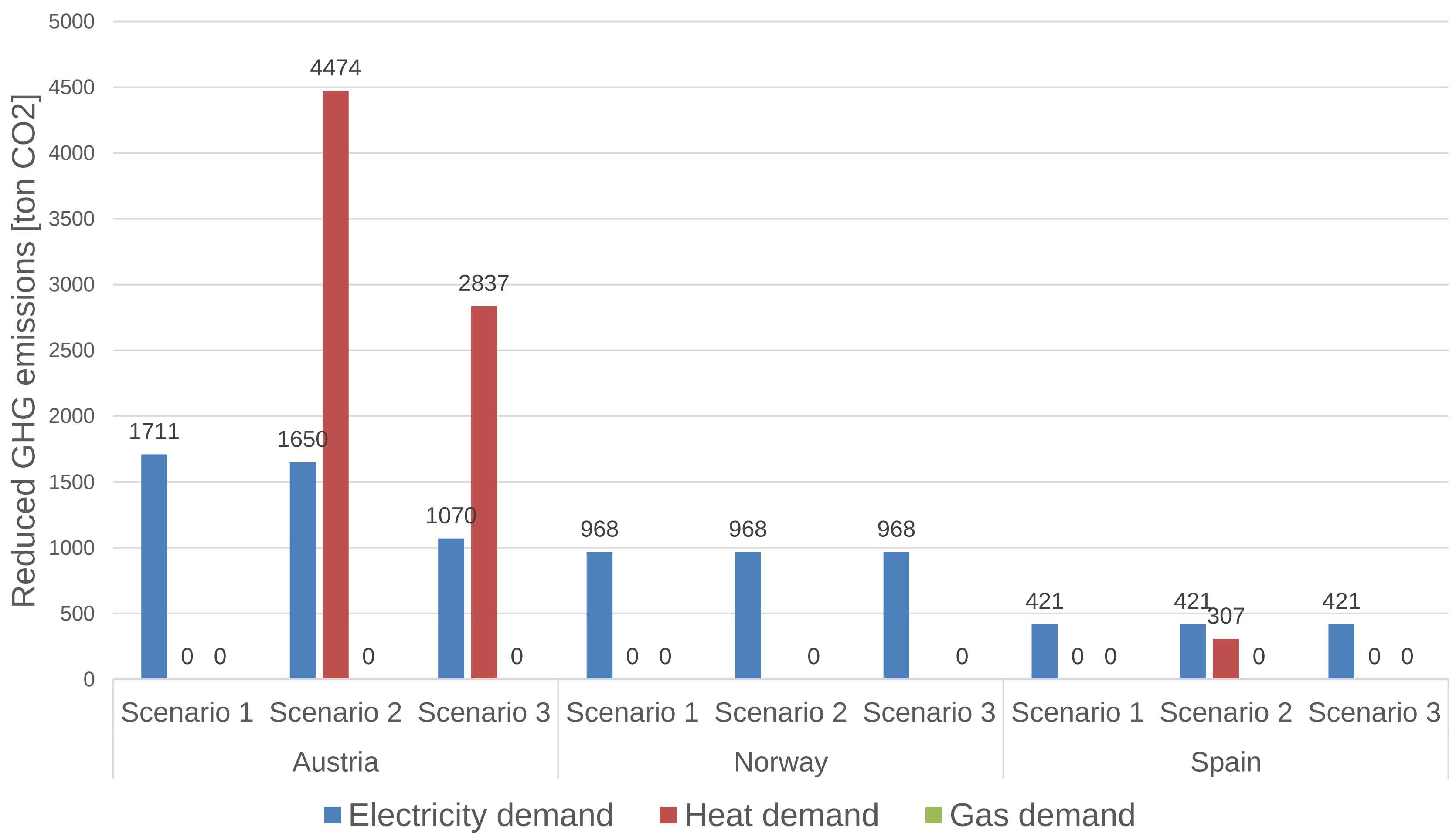
- Focusing on heat demand originally covered by district heating and gas

- Heat demand coverage in scenario 3
    - AT: Heat pump and electrolyzer
    - NO: heat pump
    - ES: electrolyzer

- Excluding heat demand covered by electricity



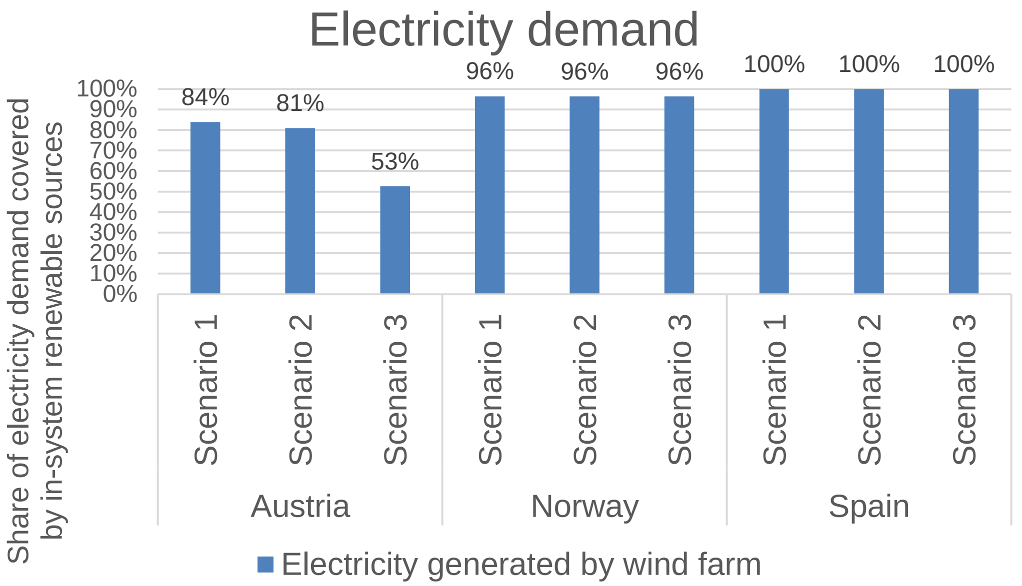
Results KPI – GHG emission reduction potential

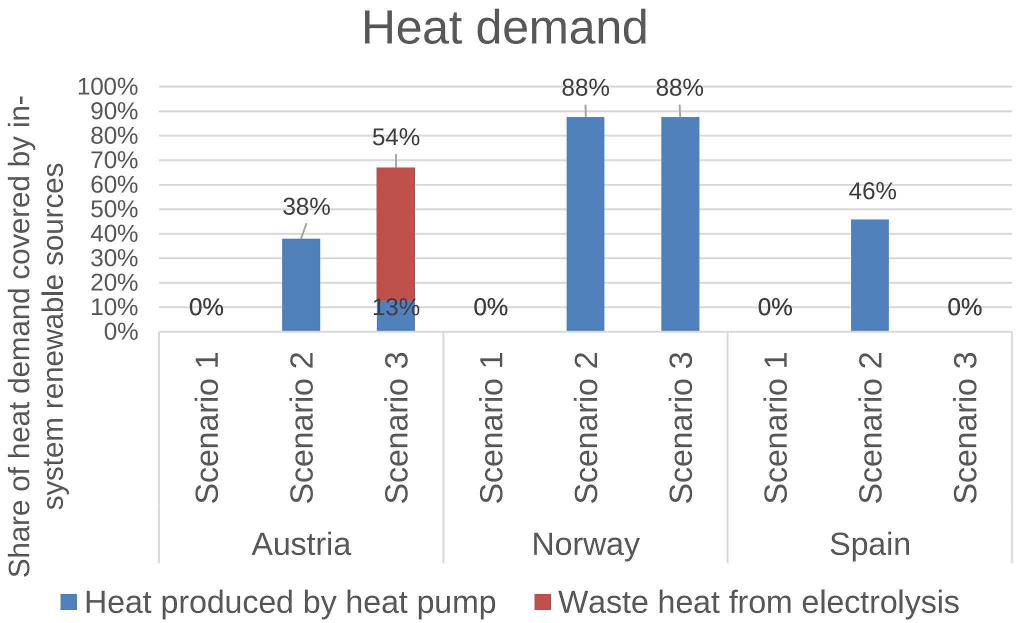


- Significant emission reduction potential
- Reduction depending on:
  - Size of technology
  - Electricity mix
  - Alternative fuel (natural gas, bio pellets)
- All green hydrogen sold to market → no emission reduction achieved

Results KPI – renewable energy self-reliance

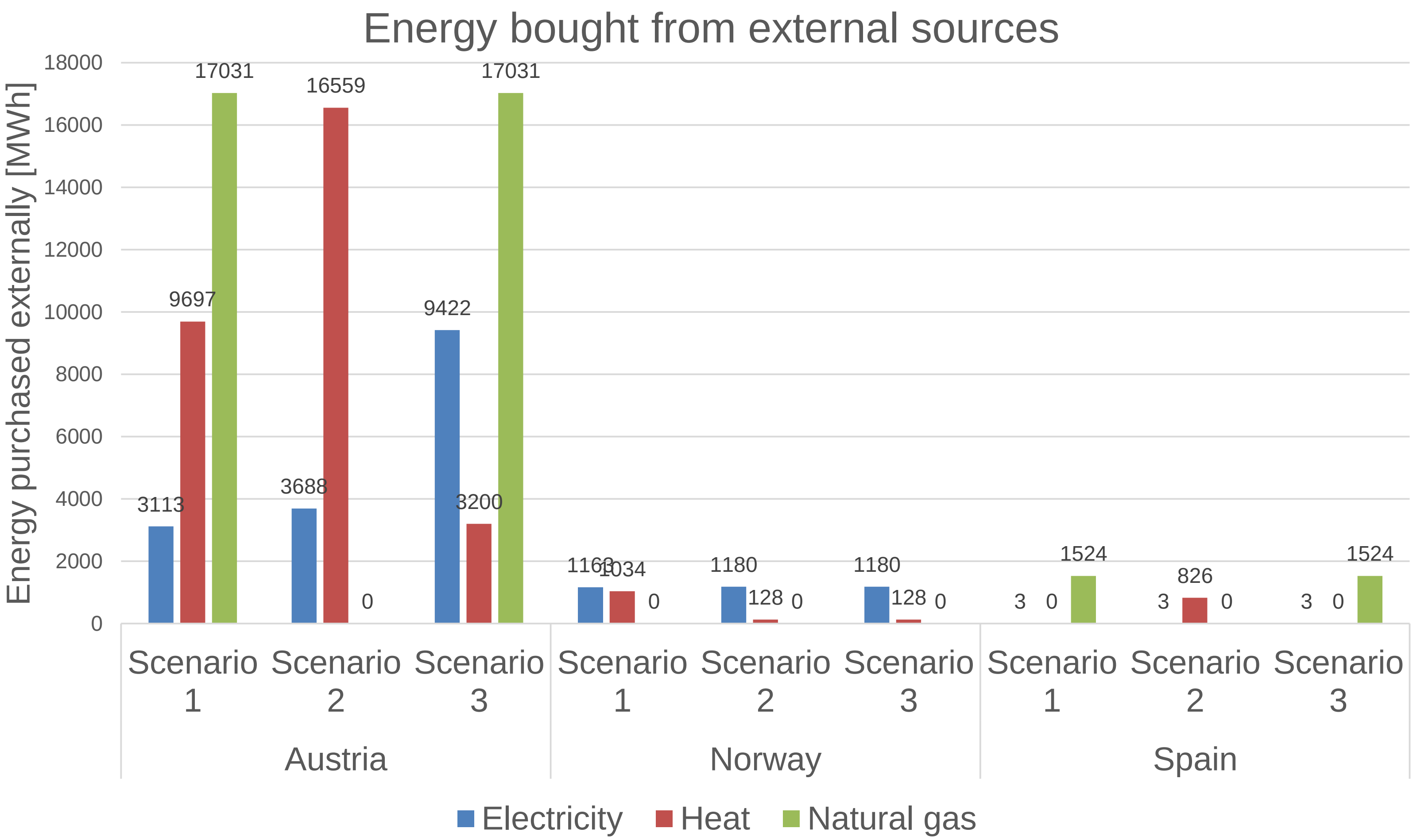
- Majority of electricity demand covered by electricity generated by wind farm
- Implementation of electrolyzer reduces degree of electricity self-reliance
- Introduction of heat pump can significantly affect degree of heat energy self-reliance





Results KPI – external energy purchase

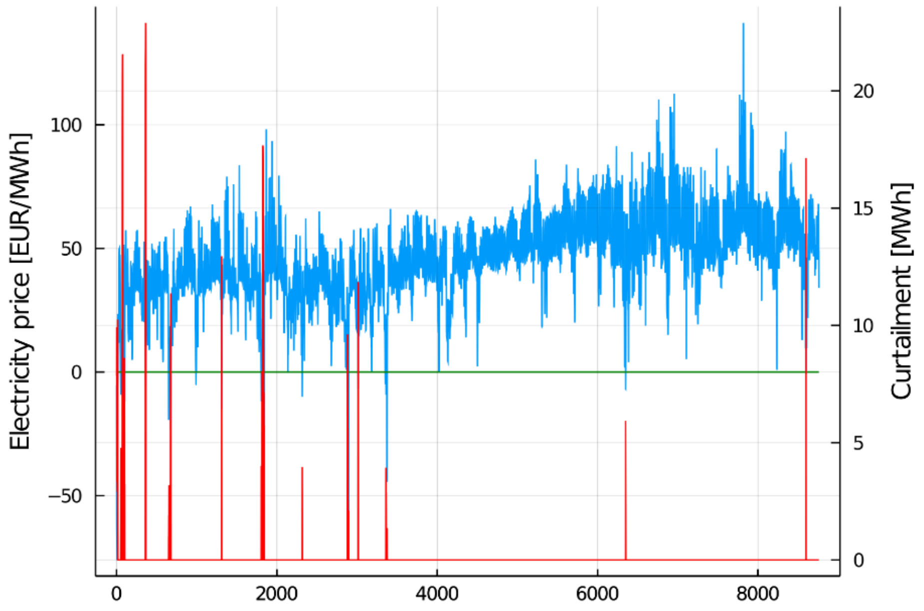
- Clear correlation with degree of energy self-reliance
- Coverage of gas demand fully dependent on natural gas purchase
- Amount of electricity bought from the grid depend on utilization and size of implemented technologies

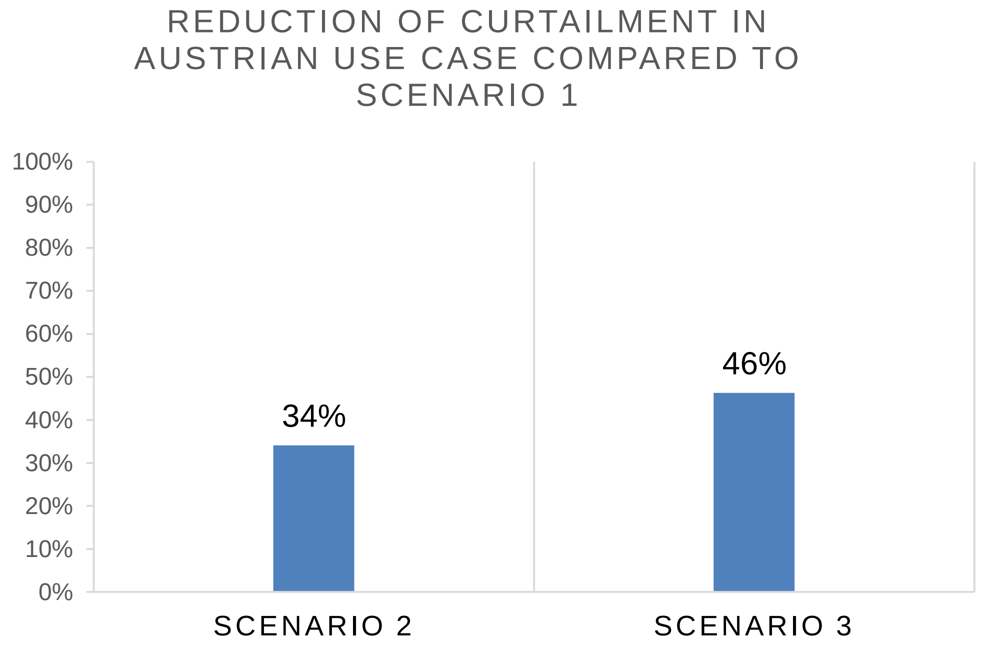


Results KPI – curtailment reduction

- Curtailment due to negative electricity prices
  - No curtailment in NO and ES

- Curtailment reduced with heat pump and electrolyzer implemented





Concluding remarks and further work

- Utilization of sector coupling concepts has the potential to reduce GHG emissions, increase degree of energy self-reliance and reduce curtailment
- Benefits of sector coupling depend on local conditions
- Further work could investigate
  - Optimal system topology when considering investment costs
  - Impact of local policy levers on influential parameters (e.g. electricity generation, energy demand, available fuel options)

References and acknowledgements

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[1] Energy Data, EuroStat, https://ec.europa.eu/eurostat/web/energy/data

[2] ThermaFLEX, Green Energy Lab, https://greenenergylab.at/en/projects/thermaflex/

Thank you!

Frida Revheim

TU Wien

Energy Economic Group, EEG

Gußhausstraße 25-29 / E370-3

1040 Vienna, Austria

Email: revheim@eeg.tuwien.ac.at

Web: http://www.eeg.tuwien.ac.at