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Flexible electricity use for heating in markets with renewable energy

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HIGHLIGHTS

- Electric heating can contribute to decarbonization and provide flexibility for renewable integration.
- Analysis of electric storage heaters for German 2030 scenarios with open-source electricity sector model.
- Temporally flexible charging of storage heaters provides only small benefits.
- Electric storage heaters not suited to align seasonal mismatch between renewables and heat demand.
- Flexible power-to-heat generally fosters use of generation technologies with low variable costs.

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ABSTRACT

Using electricity for heating can contribute to decarbonization and provide flexibility to integrate variable renewable energy. We analyze the case of electric storage heaters in German 2030 scenarios with an open-source electricity sector model. We find that flexible electric heaters generally increase the use of generation technologies with low variable costs, which are not necessarily renewables. Yet making customary night-time storage heaters temporally more flexible offers only moderate benefits because renewable availability during daytime is limited in the heating season. Respective investment costs accordingly have to be very low in order to realize total system cost benefits. As storage heaters feature only short-term heat storage, they also cannot reconcile the seasonal mismatch of heat demand in winter and high renewable availability in summer. Future research should evaluate the benefits of longer-term heat storage.

1. Introduction

Mitigating climate change demands decarbonizing energy supply, and renewable electricity sources play an essential role [1]. In Germany, often considered a frontrunner in the transition to renewables, they supplied nearly 38% of gross electricity demand in 2018, up from around 6% in 2000 [2]. For 2030, current legislation foresees a growth to at least 50%, and the German government's 2019 climate package targets an even faster growth to 65% by 2030.[1] At the same time, decarbonization must go beyond current electricity use. By 2017, more than a quarter of gross energy consumption and 14% of greenhouse gas emissions stemmed from space heating [3]. In Germany and many other countries, substantial efforts are required to reach medium- and long-term climate policy goals. One option is the use of renewable electricity in the heating and transportation sectors, often referred to as sector coupling or electrification. In its latest report on limiting global warming to 1.5 degrees Celsius, the IPCC also puts an emphasis on such electrification of end energy use [1].

While electricity generation from wind and solar PV is largely carbon neutral, it comes with two peculiarities: its supply has virtually zero variable costs, and it cannot be dispatched at full discretion. Renewables' natural variability calls for flexibility within the electricity sector to efficiently use available low-cost renewables. One option is on the demand side of the electricity market: electricity demand, which has been largely inelastic in the past, could be shifted to hours with high renewable supply and avoid hours with scarce supply.

Against this background, this paper is motivated by the twin challenges of decarbonizing space heating supply and providing flexibility for the integration of renewable electricity. Specifically, we apply an open-source electricity sector model to a German 2030 setting to analyze the system effects of flexibilizing electric heating in Germany. Current electric night-time storage heaters demand electricity at night –

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[1] See https://www.bundesregierung.de/resource/blob/975226/1679914/e01d6bd855f09bf05cf7498e06d0a3ff/2019-10-09-klima-massnahmen-data.pdf (accessed December 22, 2019).

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RealValue

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1 Background

German energy and climate policy targets

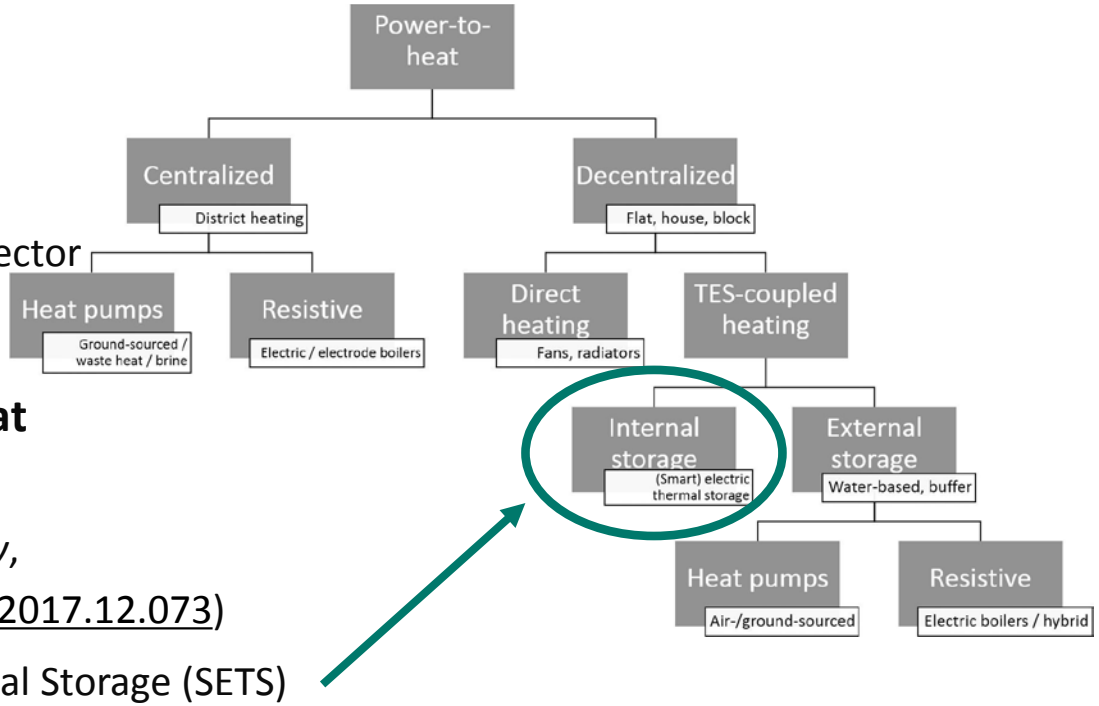
- Strongly increasing use of variable renewable energy sources
- Decarbonization of all energy sectors

Sector coupling as a strategy to

- (i) decarbonize other sectors
- (ii) provide flexibility to the power sector

Particularly promising: power-to-heat

- Many different technologies
  (cf. Bloess et al. 2018 *Applied Energy*,
  https://doi.org/10.1016/j.apenergy.2017.12.073)
- Here, focus on Smart Electric Thermal Storage (SETS)
- Analyses carried out in EU H2020 project RealValue



1 Research questions

What if SETS replaced existing night-time storage heaters in Germany?

- Question inspired by German policy / regulatory debate
- 2010: 75 mio m^2 heated by storage heaters, 13.9 TWh
- 2030 projection: 60 mio m^2, 10.6 TWh
- Not in focus: role for SETS beyond this replacement market

We investigate electricity sector effects

- Costs
- Effects on optimal generation capacity, dispatch, CO_2 emissions
- Wholesale prices

2 Model and input data

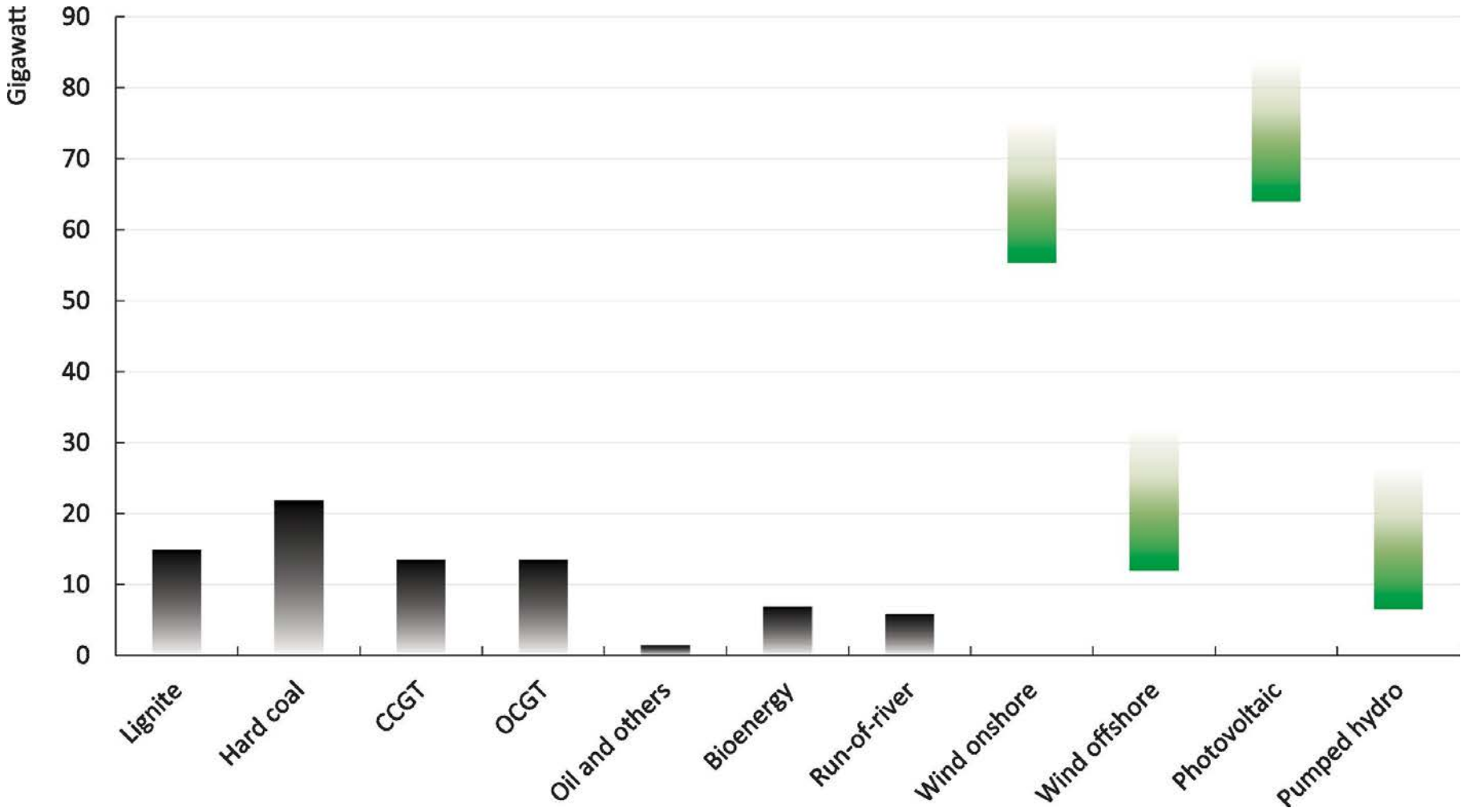
Model

- Open-source dispatch and investment model DIETER (LP, GAMS): www.diw.de/dieter
- Cost minimization over all hours of a year for the German electricity sector
- New features: domestic heat and hot water

Analysis for future scenarios of the year 2030

- Input data mainly leaning on EU Reference Scenario 2016
- Upper and lower capacity bounds
- CO_2 price assumption: 33.3 €/t

2 German generation portfolio 2030, leaning on EU reference scenario



2 Scenarios and sensitivities

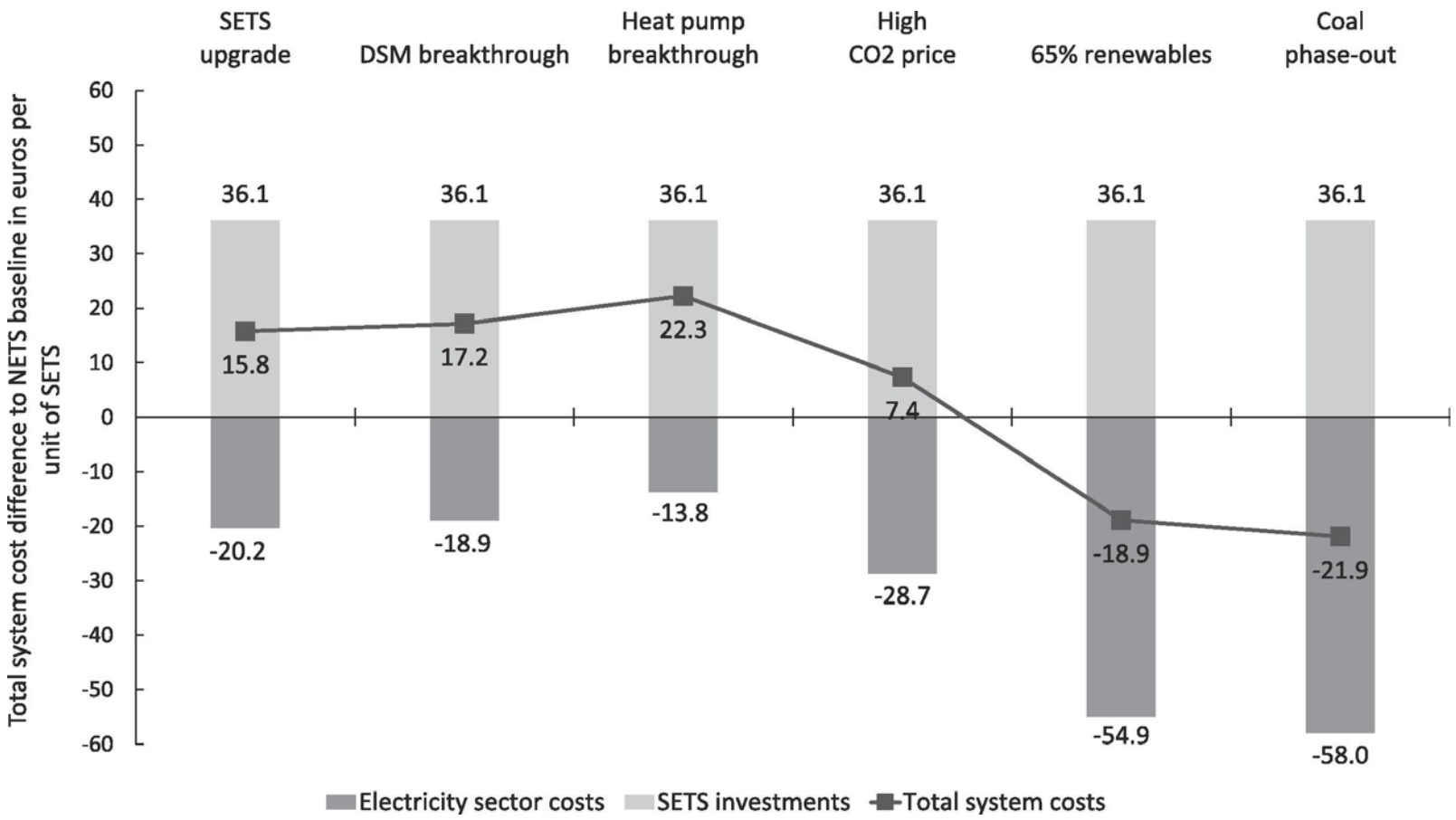
Baseline: night-time electric thermal storage heaters ("NETS")

Central scenario: „SETS upgrade" in which NETS are fully replaced by SETS

Further scenarios (each with respective baseline)

- DSM breakthrough: demand-side management available (load shifting, load shedding)
- Heat pump breakthrough: 10% heat pumps in all building types
- High CO_2 price: CO_2 price of 71 Euro/ton according to TYNDP 2016
- 65% renewables
- Coal phase-out: no lignite, hard coal capacities at most 16.5 GW, 65% renewables

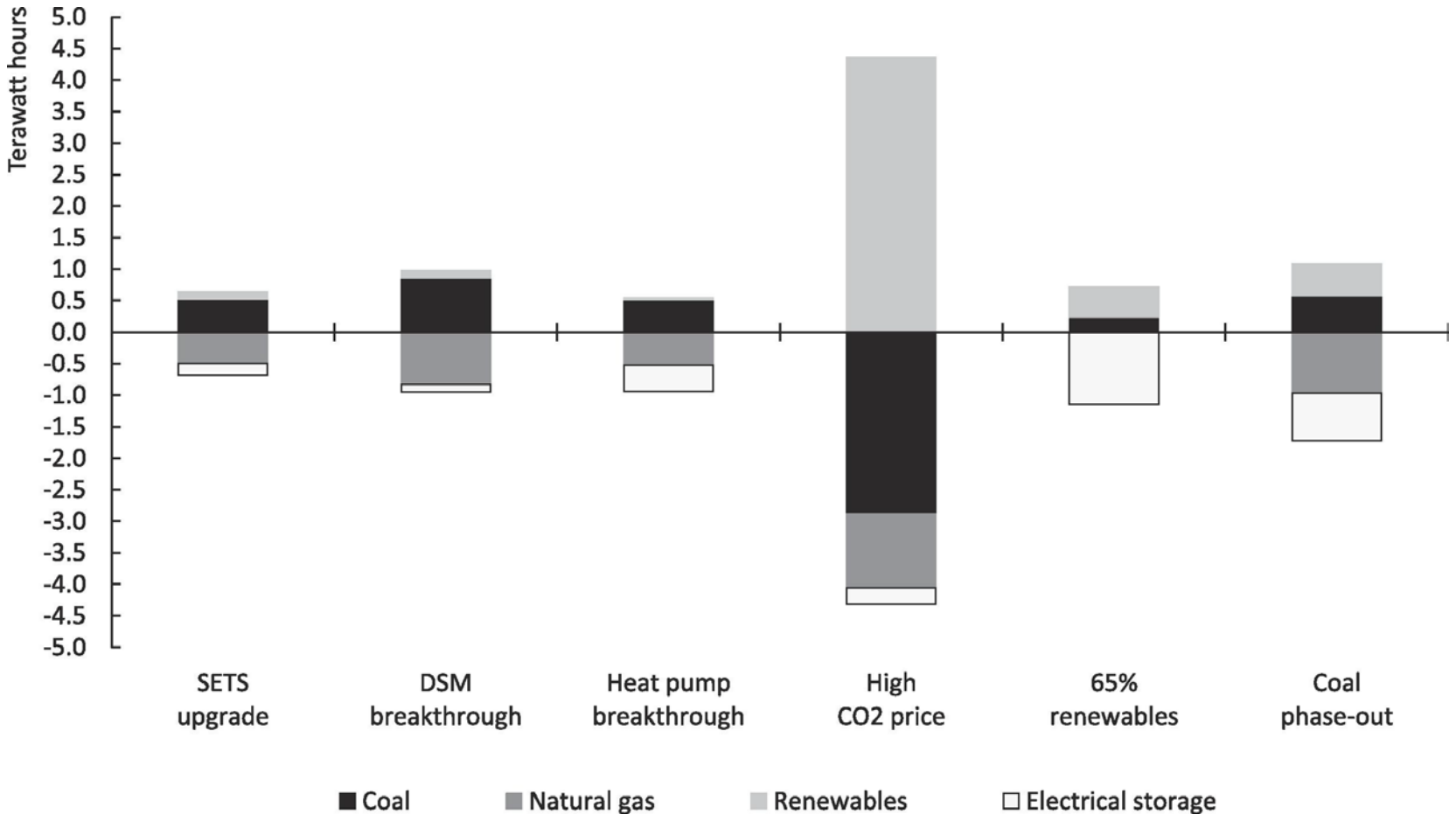
3 Results: electricity sector costs and total system costs



→ Flexibility of SETS less valuable of other sources of flexibility are available, but more valuable for higher shares of variable renewables

→ Overall, not much money on the table…

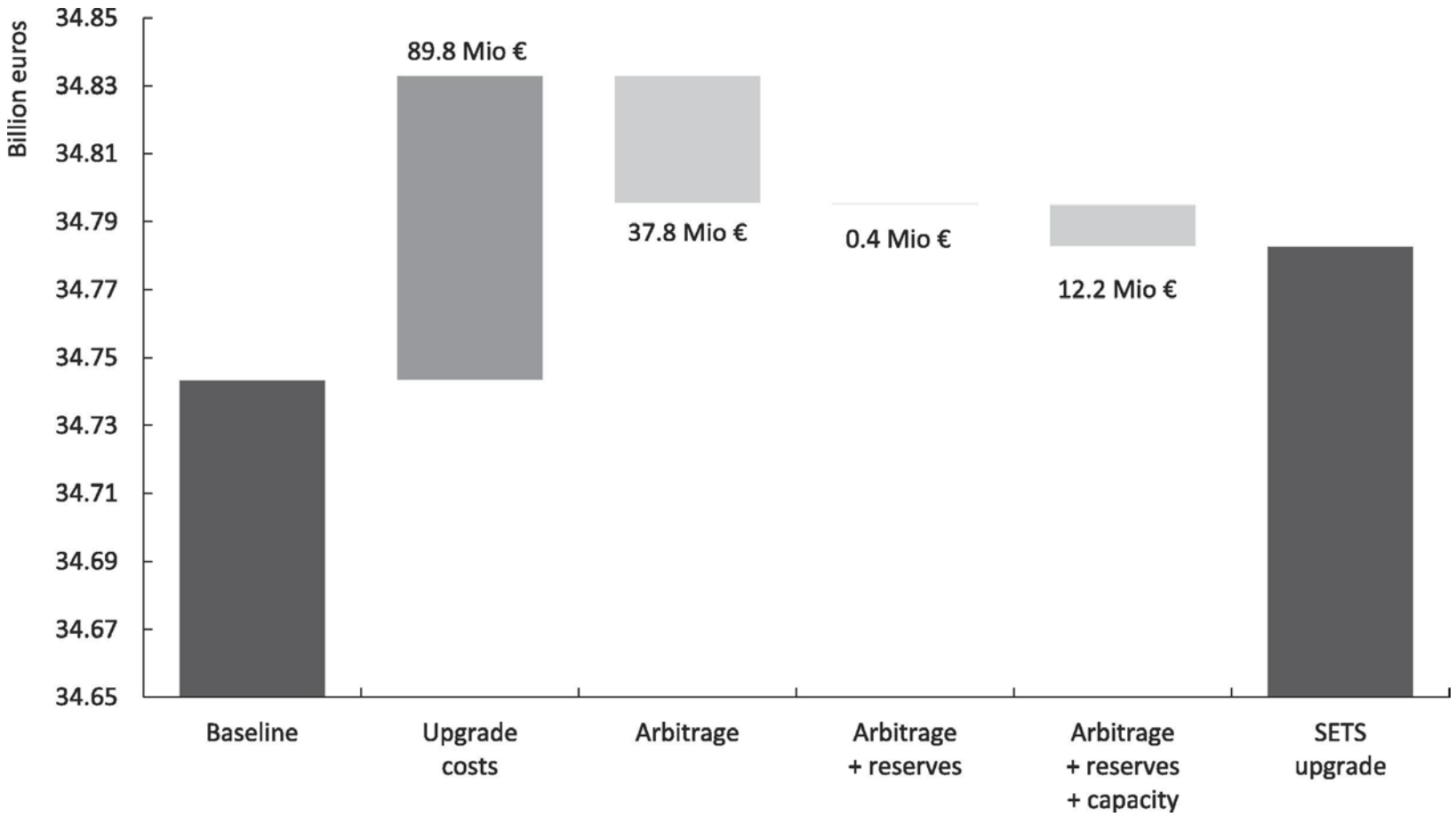
3 Results: Differences in annual electricity generation cp. to NETS baselines



→ SETS are agnostic: they substitute electrical storage and help make better use of cheap generation

→ Depending on CO_2 price, this may be coal or additional renewables

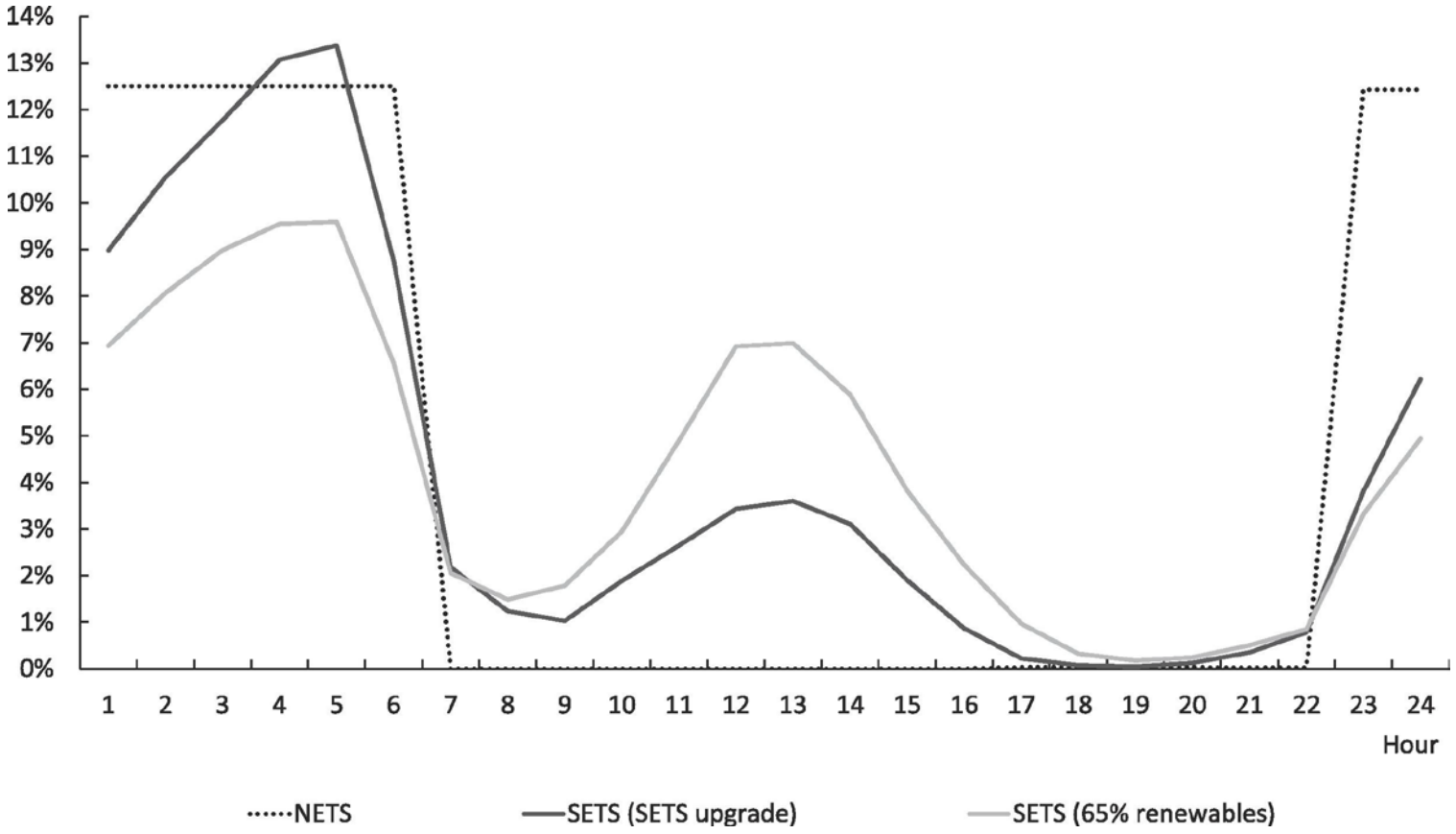
3 Results: separation of system values



→ Most system cost savings are due to arbitrage → main business model?

→ Reserve value negligible, additional system cost savings due to capacity or portfolio value

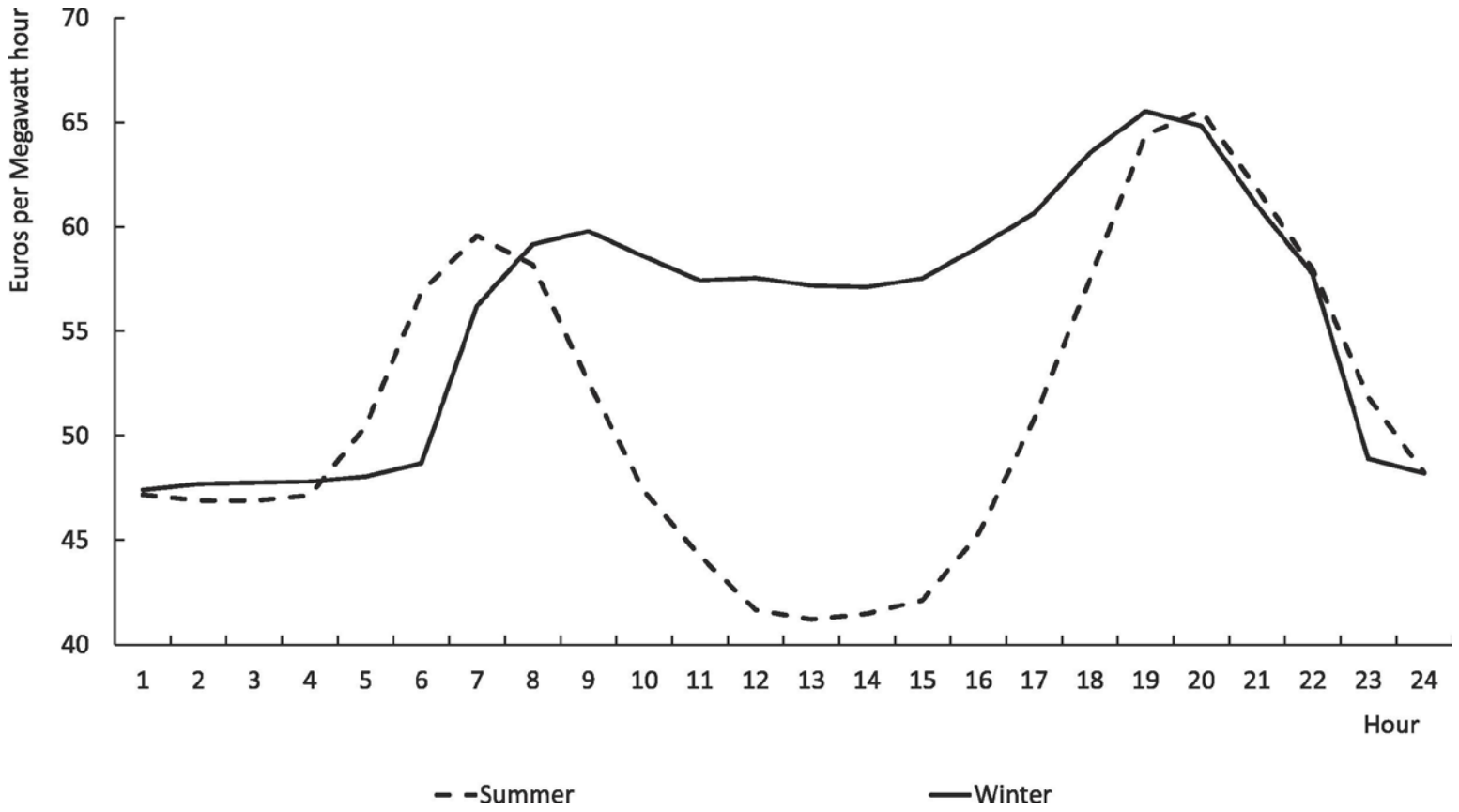
4 Discussion: Why are system cost benefits rather moderate?



→ SETS upgrade scenario: SETS charge more than 75% of annual electricity demand at night

→ 65% renewables scenario: SETS charge 60% of annual electricity demand at night

4 Discussion: Seasonal hourly electricity prices (SETS upgrade scenario)



→ 80% of heat demand in winter and fall

→ Prices in heating season still lowest at night-time

→ No substantial price advantage from flexibility

5 Conclusion

Temporal flexibility is agnostic about electricity it helps to integrate

- Benefits for renewables depend on shape of merit order

Flexibilizing storage heaters only leads to moderate benefits

- Arbitrage value > capacity value >> reserve value
- Respective investment costs would have to be very low

Results driven by temporal mismatch of renewable availability and heat demand

- Prices in heating season still lowest at night-time in medium run

In the longer run, other power-to-heat options more promising

- Only niche role for SETS in the heating sector transformation
- In the long run, much larger role for heat pumps + longer-term heat storage

Thank you for listening

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