DIW BERLIN

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Flexible residential power to heat for renewable energy integration

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RealValue

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1 Background

German energy and climate policy targets

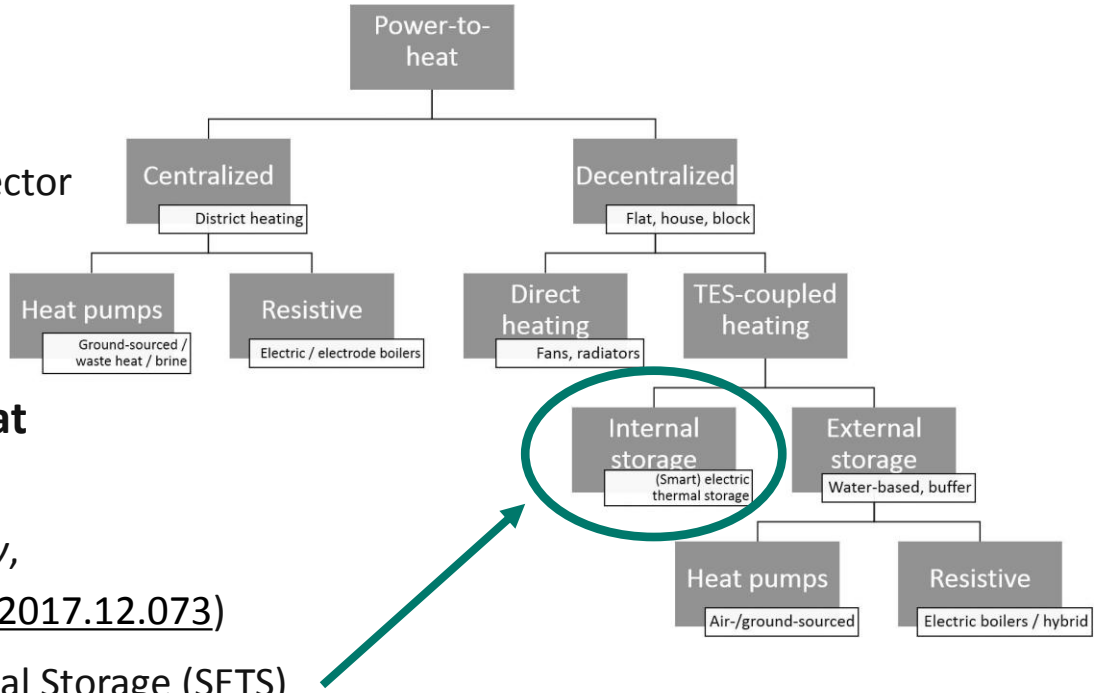
- Strongly increasing use of variable renewable energy sources
- Decarbonization of all energy sectors

Sector coupling as a strategy to

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

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?

- 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 effects in the electricity system

- Total system costs
- Optimal dispatch, CO_2 emissions
- Wholesale prices

We also separate different system values: arbitrage, reserves, capacity

2 Model and input data

Model

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

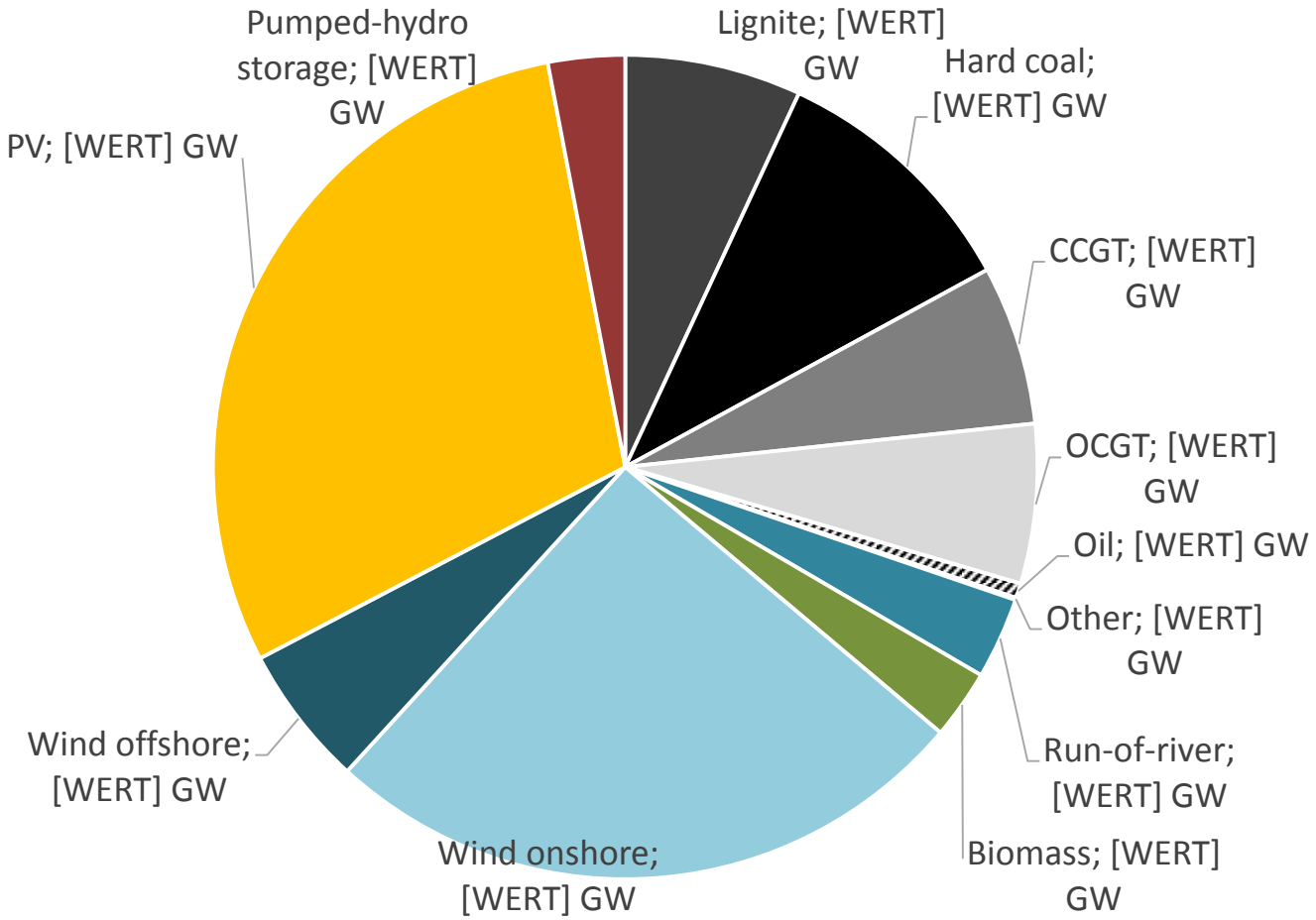
Analysis for future scenarios of the year 2030

- Input data mainly leaning on EU Reference Scenario 2016
  - Exogenous thermal capacities as upper bounds
  - Exogenous renewable and pumped-hydro storage capacities as lower bounds
  - Unbounded investments in lithium-ion batteries and P2G2P storage
- CO_2 price assumption: 33.3 €/t

Disclaimer

- We model Germany only
- We largely abstract from investment costs of P2H options
- No other sector coupling considered, e.g. no electric vehicles or P2X

2 German generation portfolio 2030, leaning on EU reference scenario



2 Model and input data: residential heating

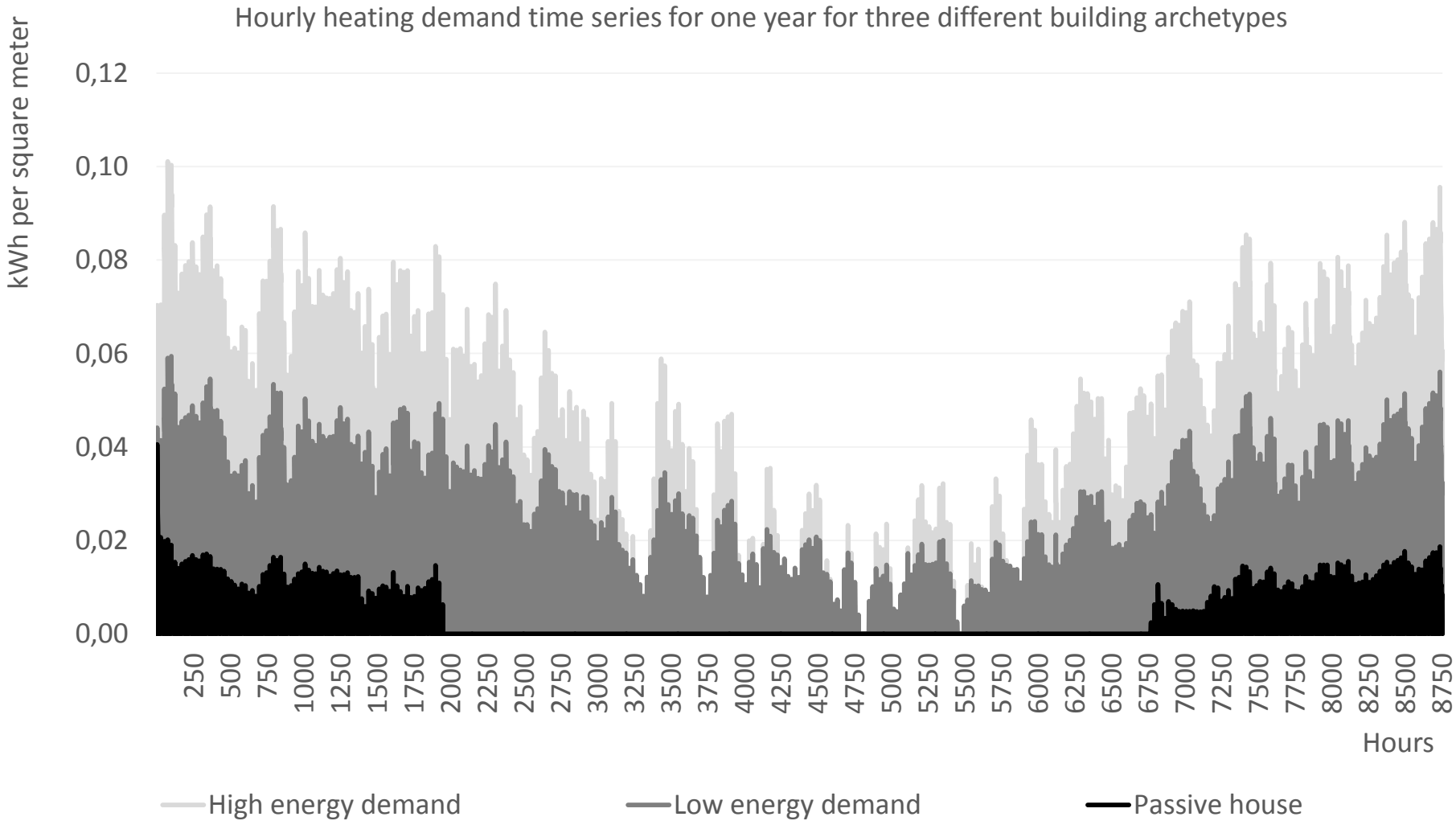
Different electric heating technologies for space heating and DHW

- Night-time electric storage heating (NETS)
- SETS
- Heat pumps (ground-sourced, air-sourced)
- Direct electric heating
- Hybrid heating (combination of the above, or with natural gas or oil)

Twelve building archetypes

- Six energy efficiency classes, two building types
- Hourly heating demand profiles generated by RWTH Aachen for test reference year
- Projection of future floor area developments of all archetypes, considering energy efficiency improvements

2 Model and input data: residential heating



2 Scenarios and sensitivities

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

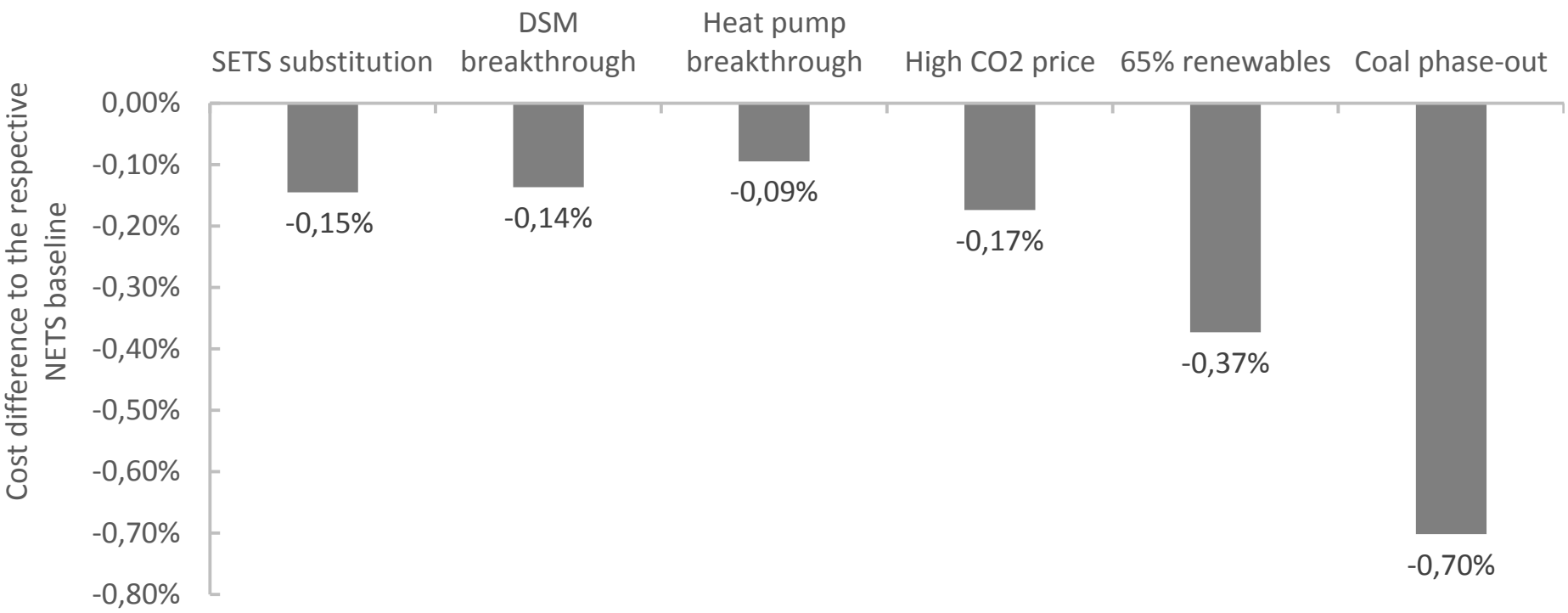
- NETS assumed to be present in historic load profile

Central scenario: „SETS substitution" 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 type
- 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: system cost savings for SETS substitution



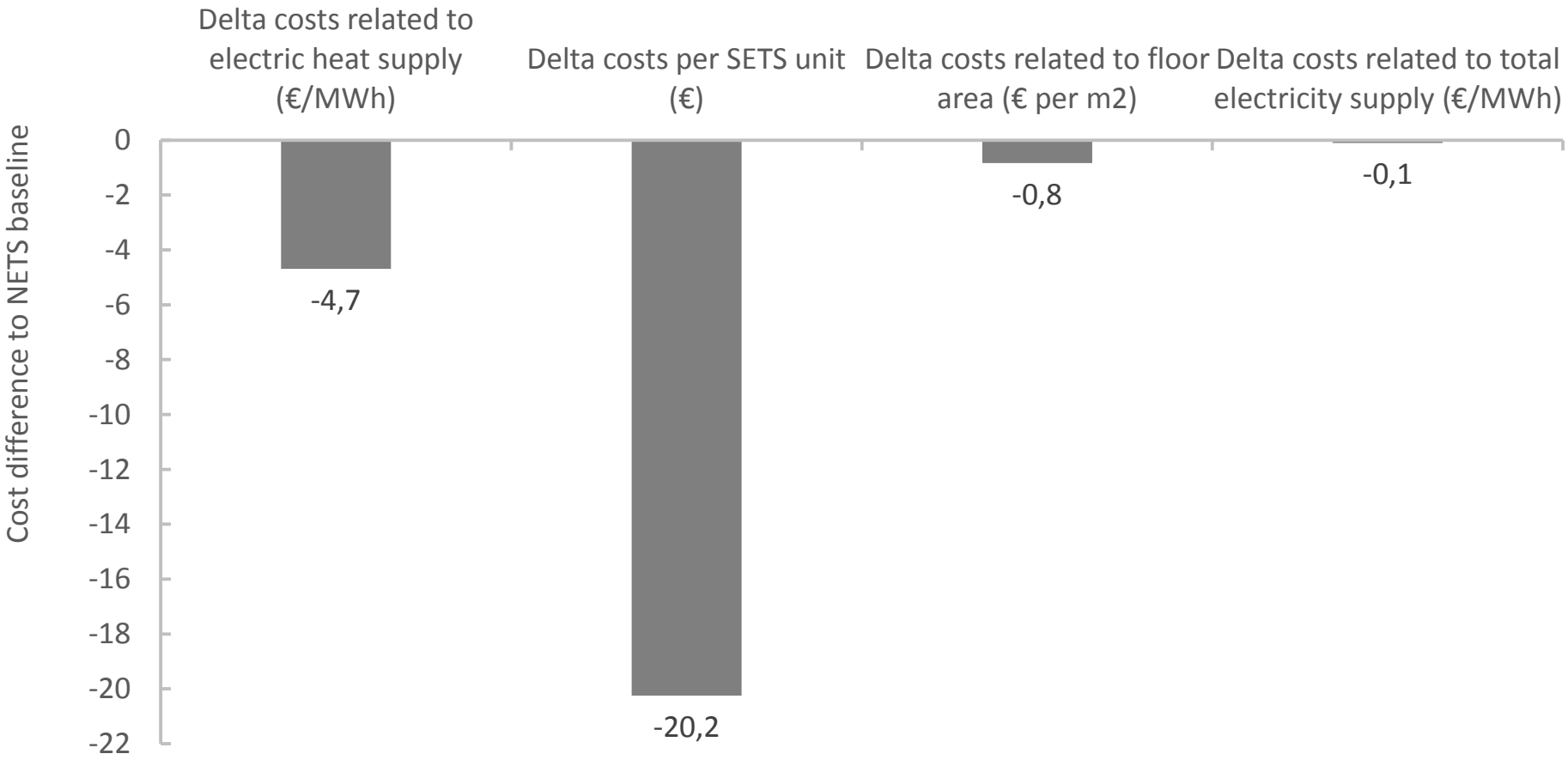
→ System cost benefit of SETS lower if more other sources of flexibility available

→ Flexibility of SETS more valuable with more variable renewables in the system

→ Flexibility of SETS more valuable if the merit order is steeper

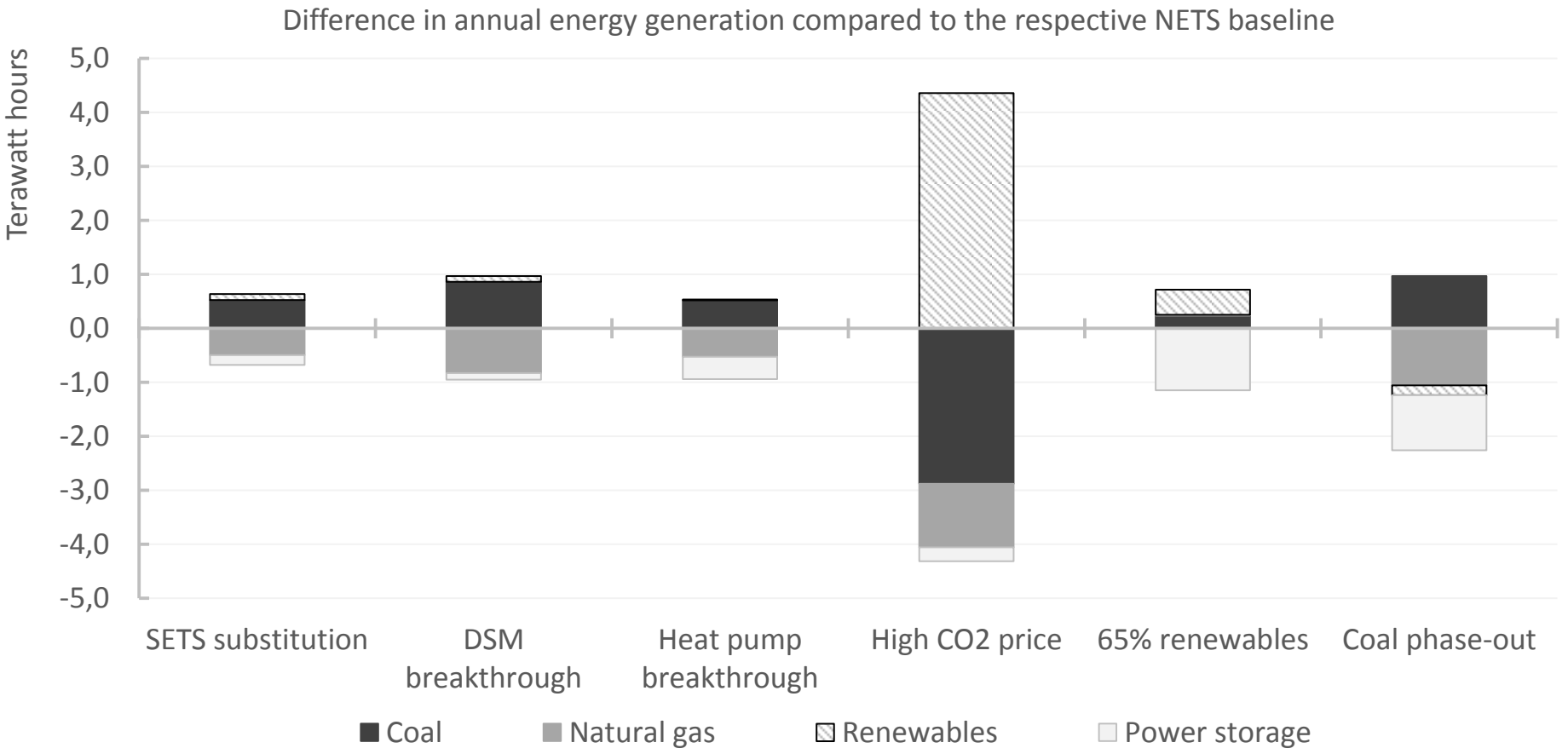
→ Overall efficiency gains from improving the charging patterns of storage heaters rather moderate

3 Results: specific system cost savings for SETS substitution



→ Upper boundary for consumer benefits: not much money on the table

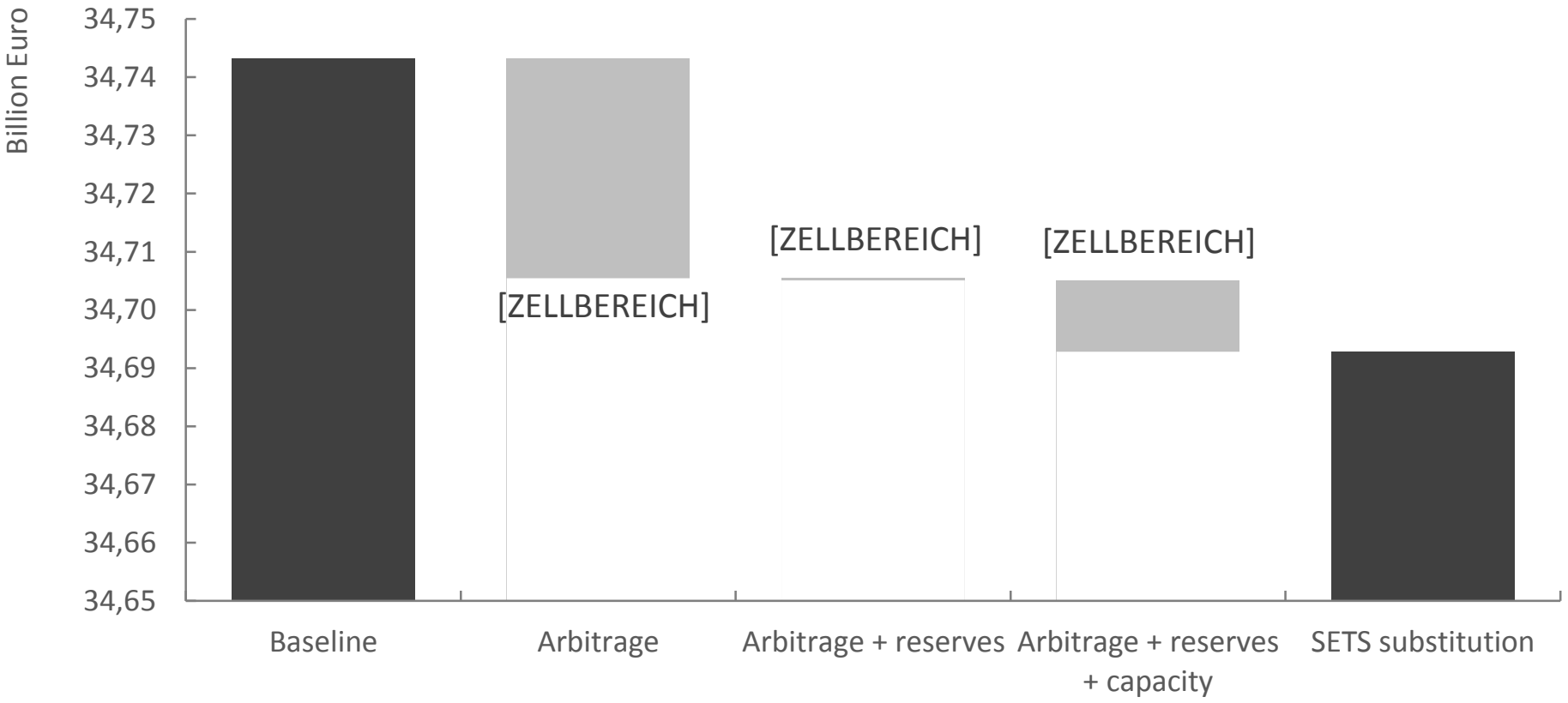
3 Results: dispatch effects for SETS substitution



→ SETS are agnostic: they substitute power 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

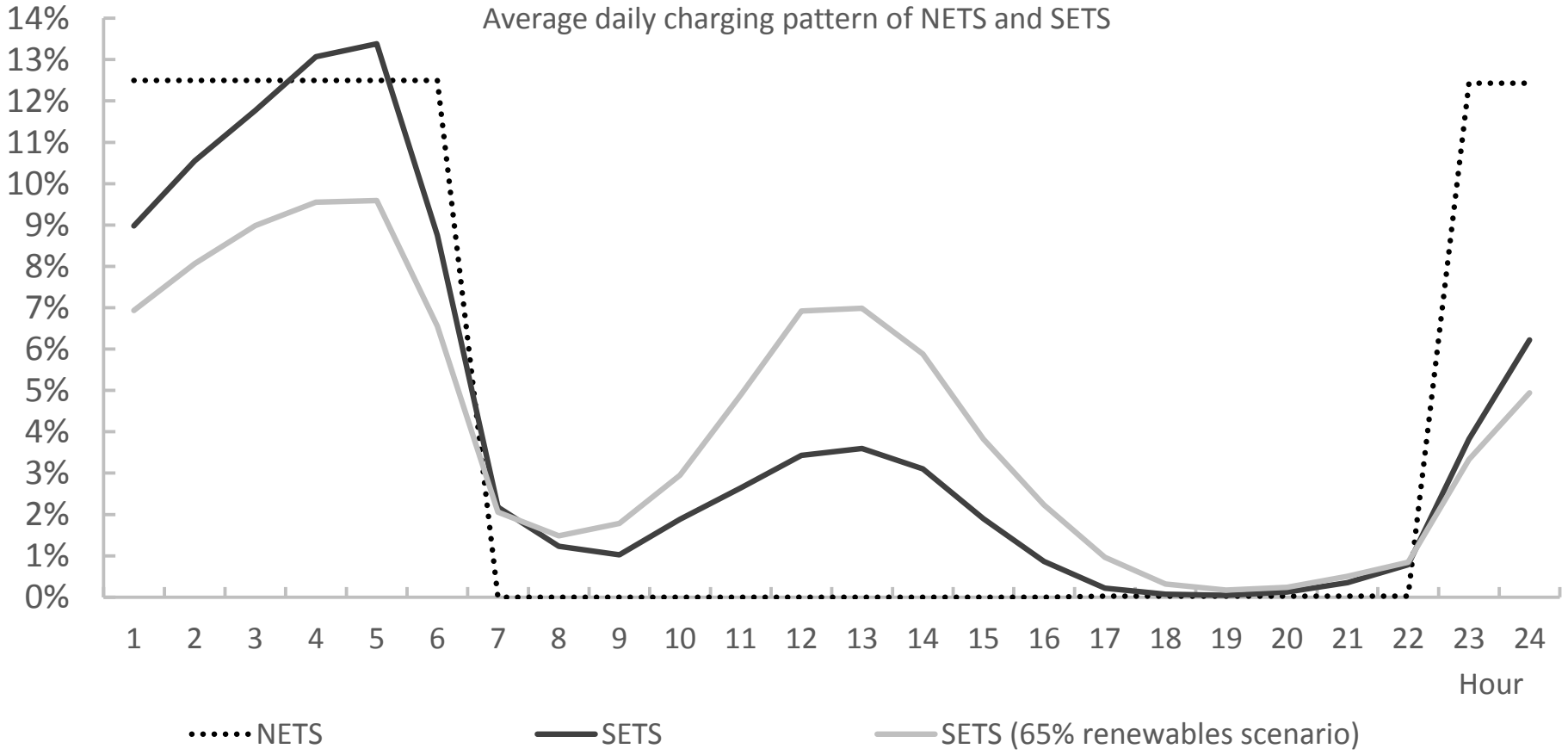


→ Most system cost savings are due to arbitrage

→ Reserve value negligible

→ Around one quarter of system cost savings due to capacity or portfolio value

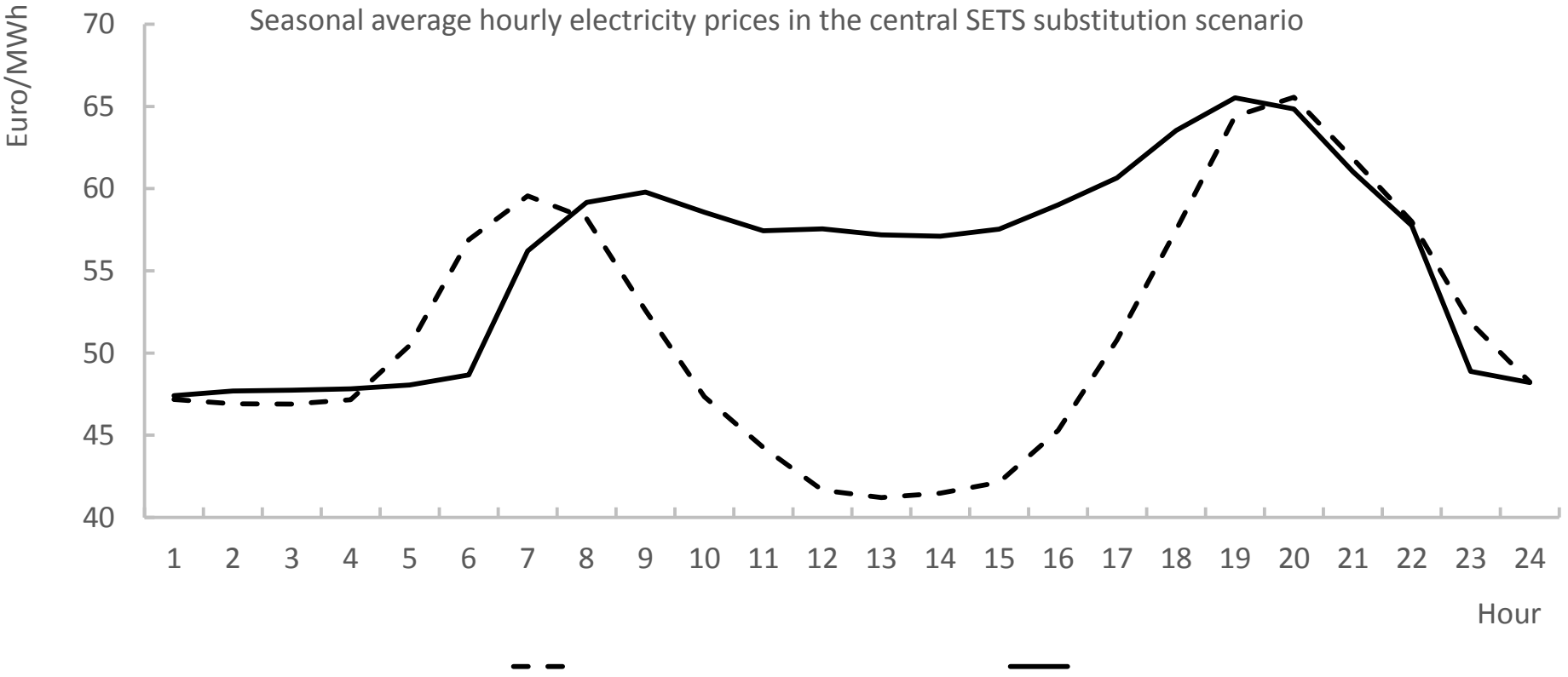
4 Discussion: Why are system cost benefits rather moderate?



→ SETS substitution 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: Duck-shaped curves

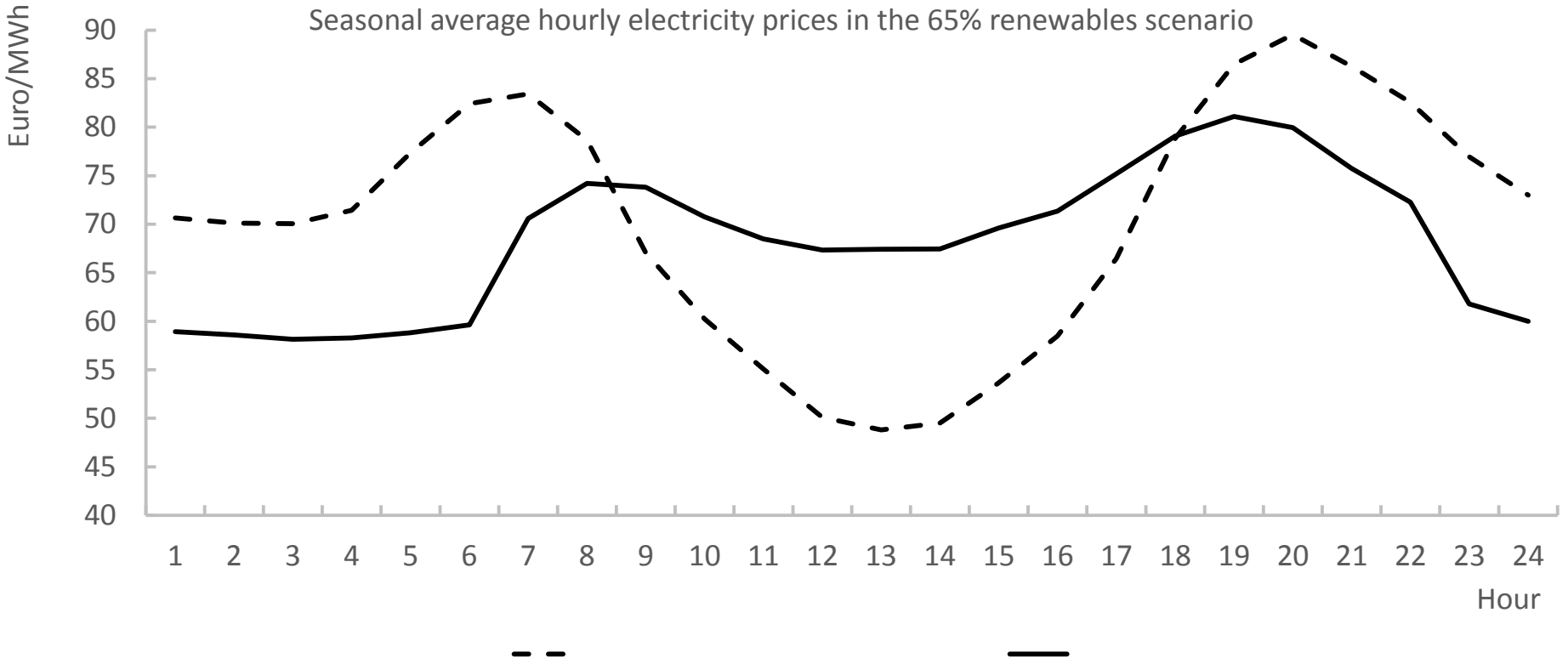


→ 80% of heat demand in winter and fall

→ Prices in heating season still lowest at night-time

→ No substantial price advantage from flexibility

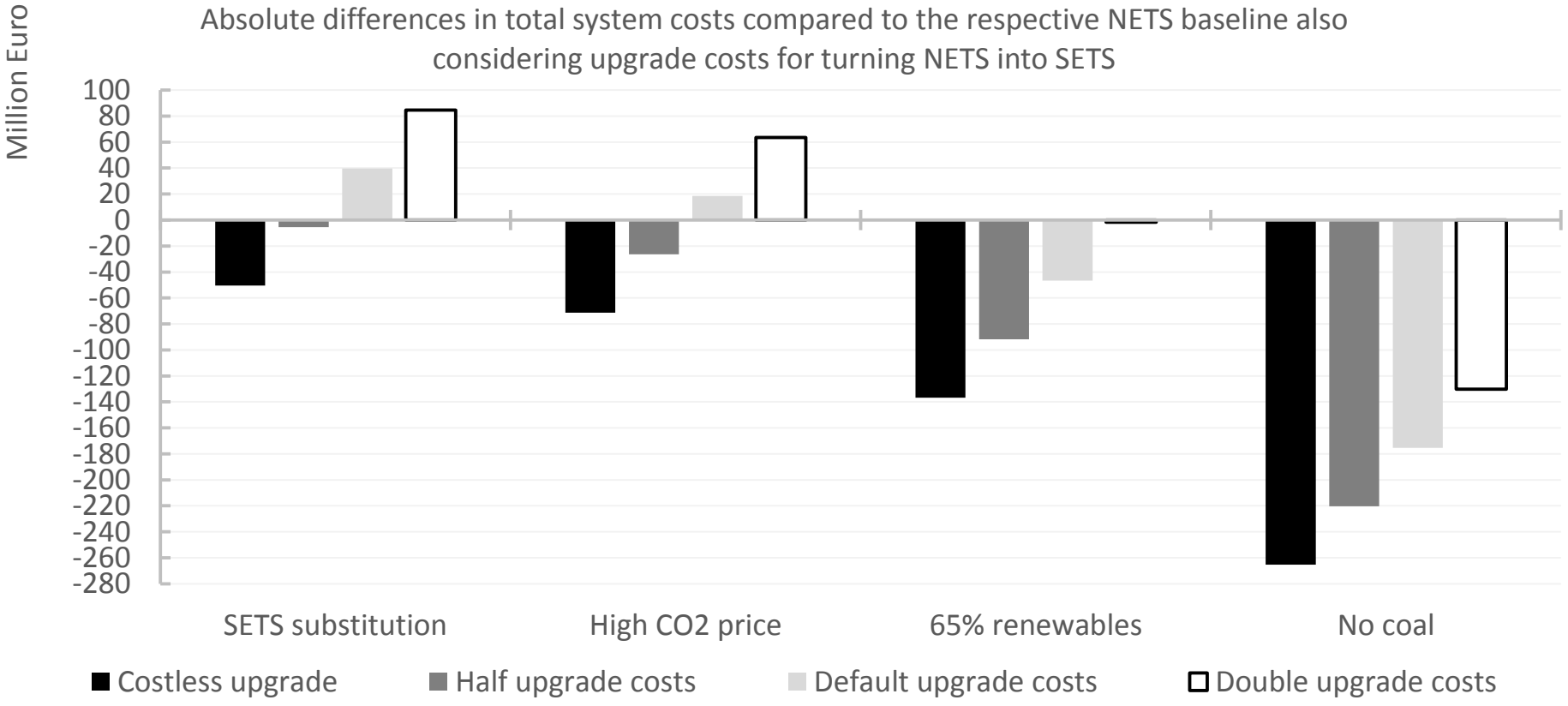
4 Discussion: less „ducky“ prices with more renewables



→ More pronounced PV dip also in winter

→ Flexibility more valuable

4 Discussion: NETS upgrades must be cheap to be economical



→ Default cost assumption for flexibilizing a night-time storage heater: 1.13 €/kWh

→ Overall positive impact only in high renewables scenarios

5 Conclusion

System values of SETS

- Demand-side flexibility complements ambitious renewable goals
- Arbitrage value > capacity value >> reserve value

Flexibilizing storage heaters comes with moderate benefits under default assumptions

- Prices in heating season still lowest at night in medium run
- Other flexibility options more likely to be favorable

Temporal flexibility is agnostic

- Benefits for renewables depend on shape of merit order

Comparison with other P2H options

- SETS unlikely to be a major strategy for the heating sector transformation
- Heat pumps more likely to play a major role for the (large) heating segment excluded here

  → much lower electricity consumption, lower (variable) costs

Thank you for listening

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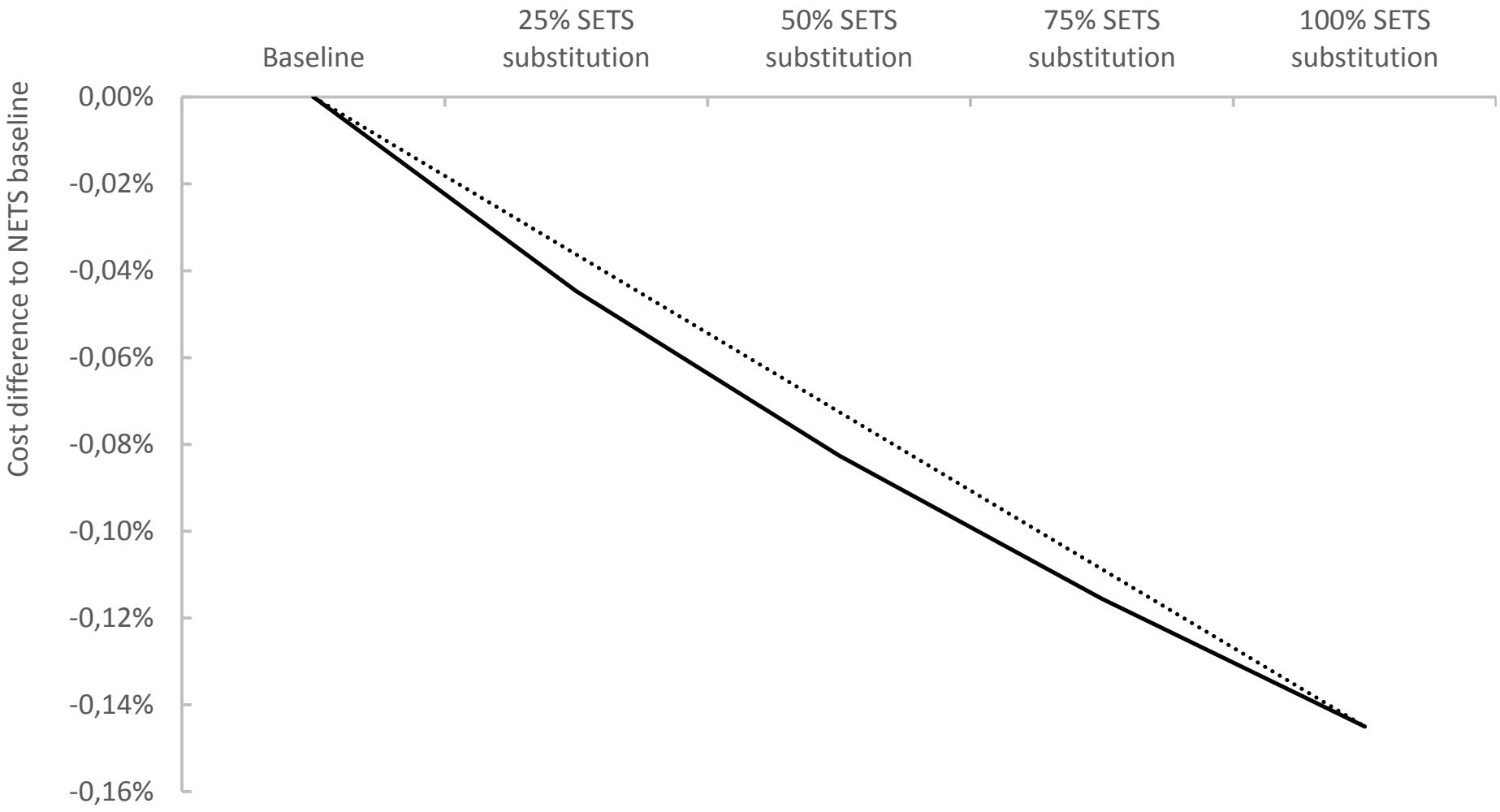
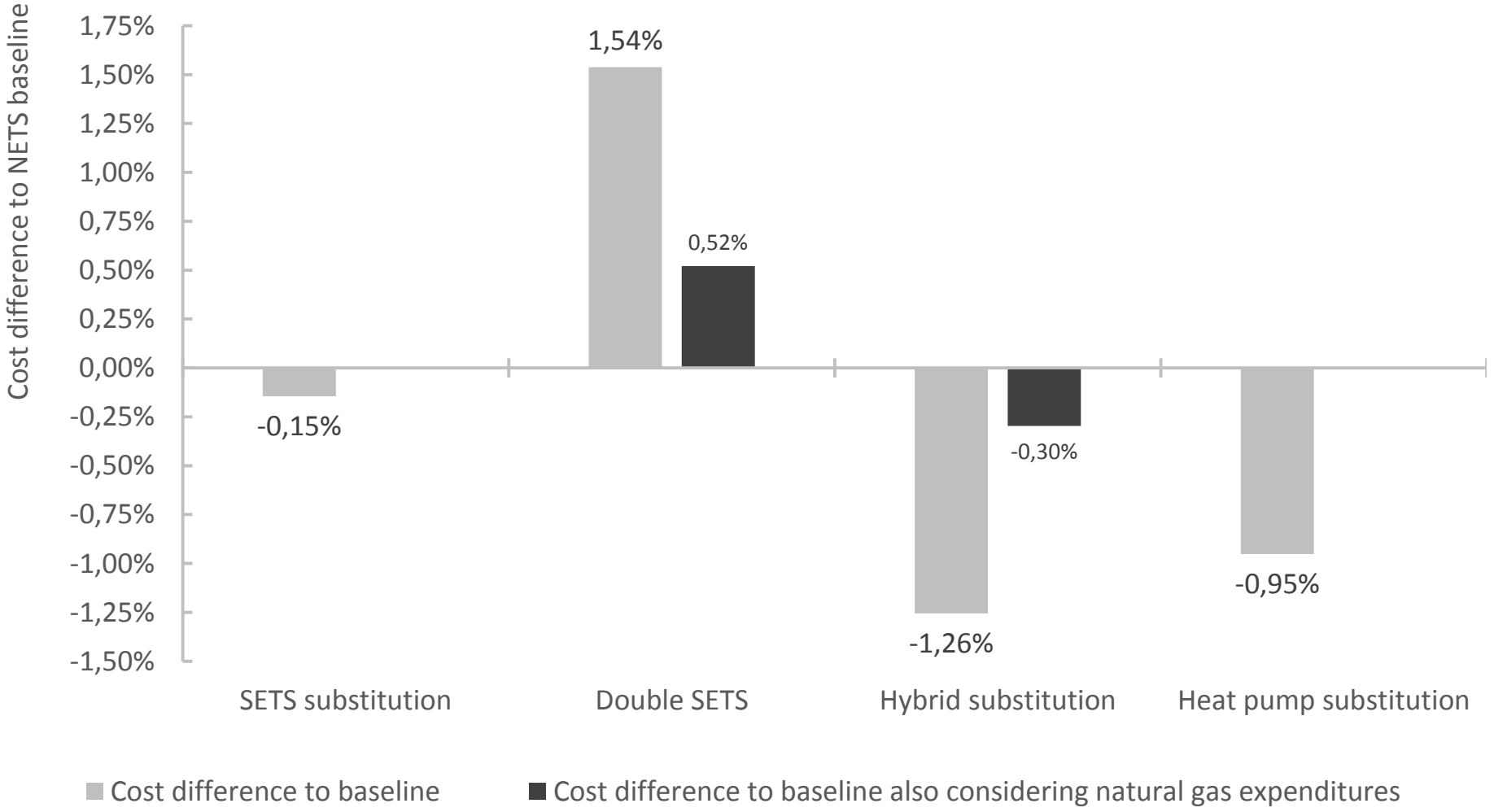
Projection of building archetypes and heating energy demand

	Description		Annual heating energy demand	Floor area w/ NETS/SETS	Floor area w/ heat pumps
			[kWh/m^2]	[million m^2]	[million m^2]
b1	One-family house	very high energy demand	276	7.15	2.47
b2	Multi-family house		223	3.58	2.22
b3	One-family house	high energy demand	203	12.50	4.31
b4	Multi-family house		164	6.75	4.18
b5	One-family house	medium energy demand	153	16.49	7.57
b6	Multi-family house		130	5.74	0
b7	One-family house	low energy demand	112	6.87	32.23
b8	Multi-family house		103	0.98	3.35
b9	One-family house	very low energy demand	66	0	103.88
b10	Multi-family house		51	0	28.96
b11	One-family house	passive house	15	0	127.67
b12	Multi-family house		11	0	37.15

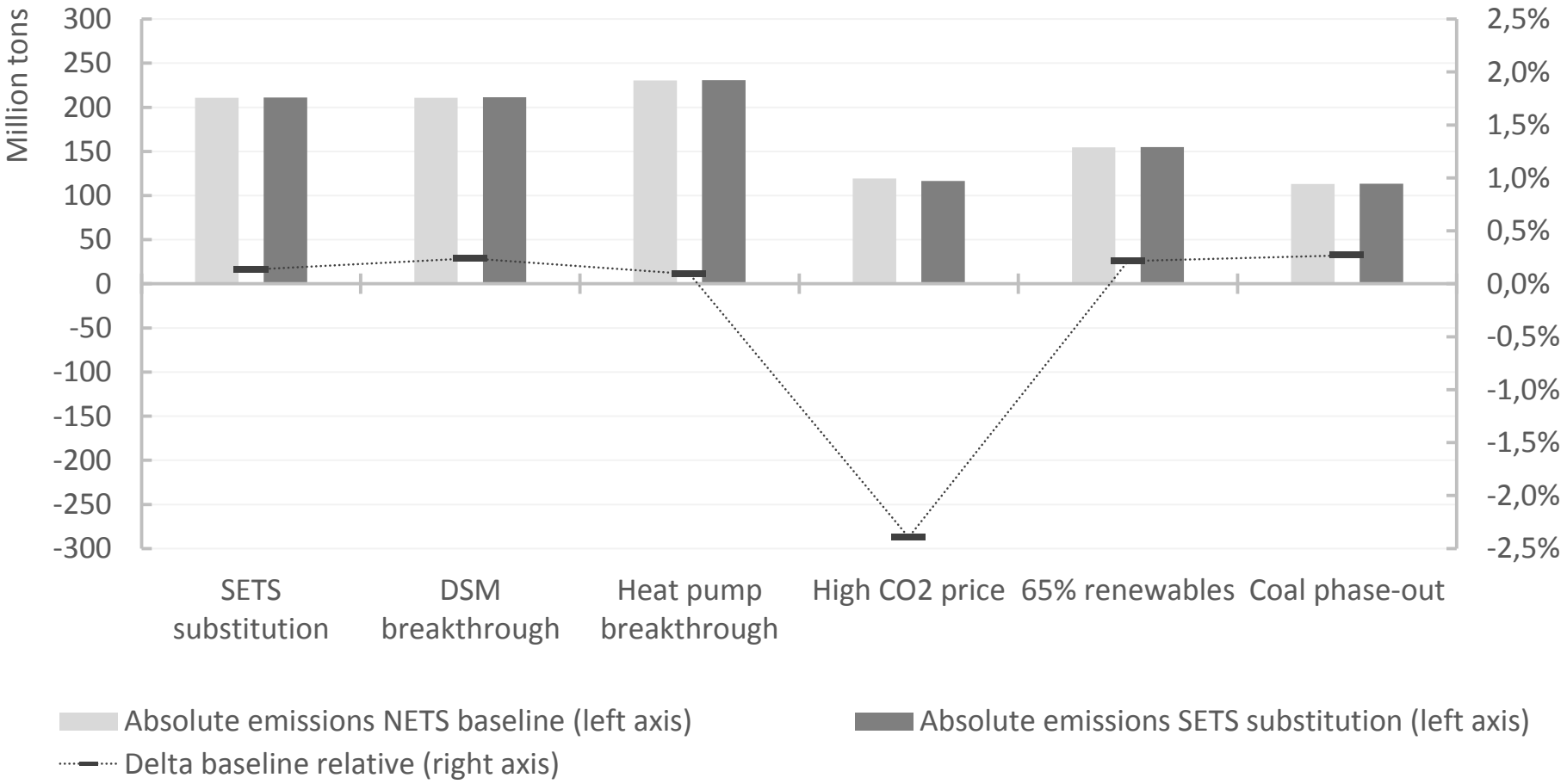
System cost savings in case of partial NETS substitution



System cost savings for further NETS substitution scenarios



Results: CO_2 emissions



→ CO2 emissions reflect the dispatch

Results: Electricity wholesale prices