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Electricity Markets with Capacity Remuneration including Energy Storage

Master thesis 2016 and further work

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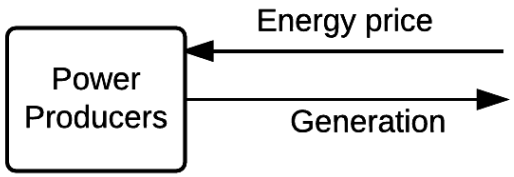
MCP Equilibrium Modeling

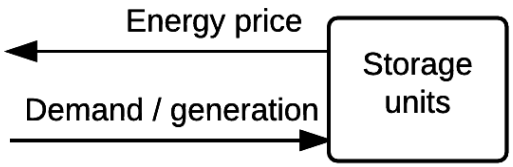
- Widely used in economic applications
- Useful for market mechanisms
- Each market participant is formulated separately and coupled through market(s)

- **Goal: Analyze how the introduction of storage units affects the rest of the system in a scenario with high levels of renewable energy.**

Method

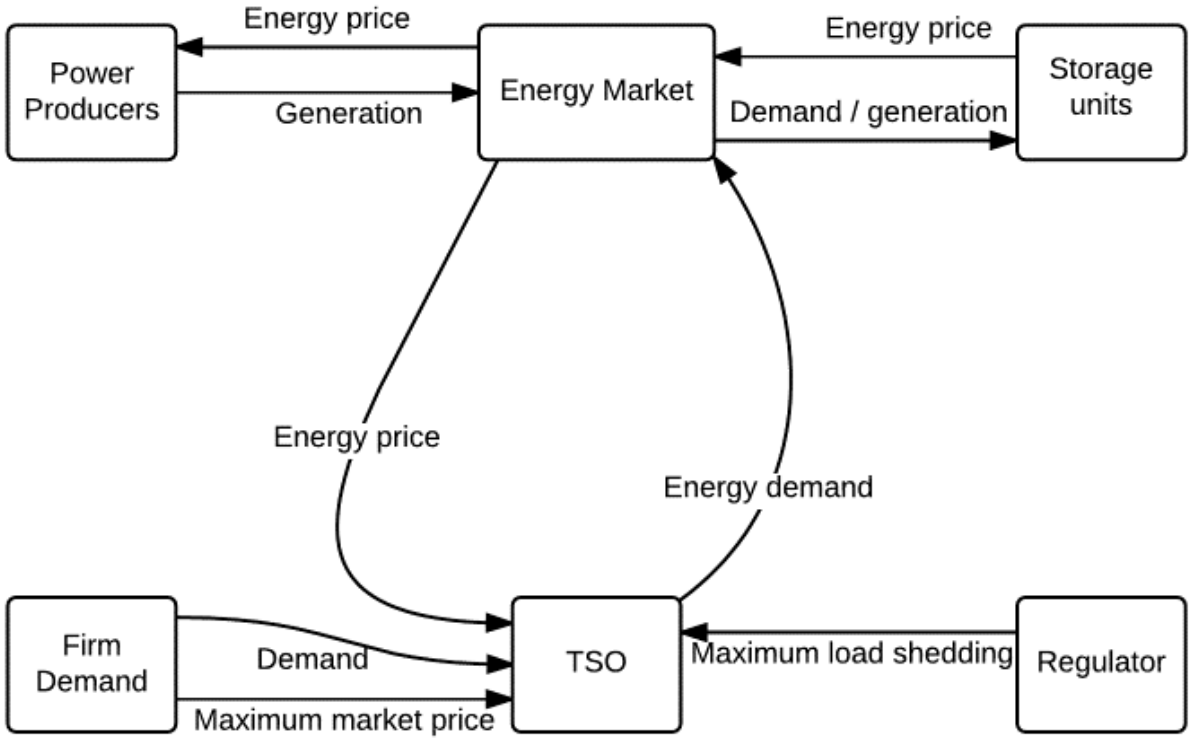
- Producers and storage units are price-takers
- Optimizes production and investments





Method

•Demand side and production coupled through the energy market



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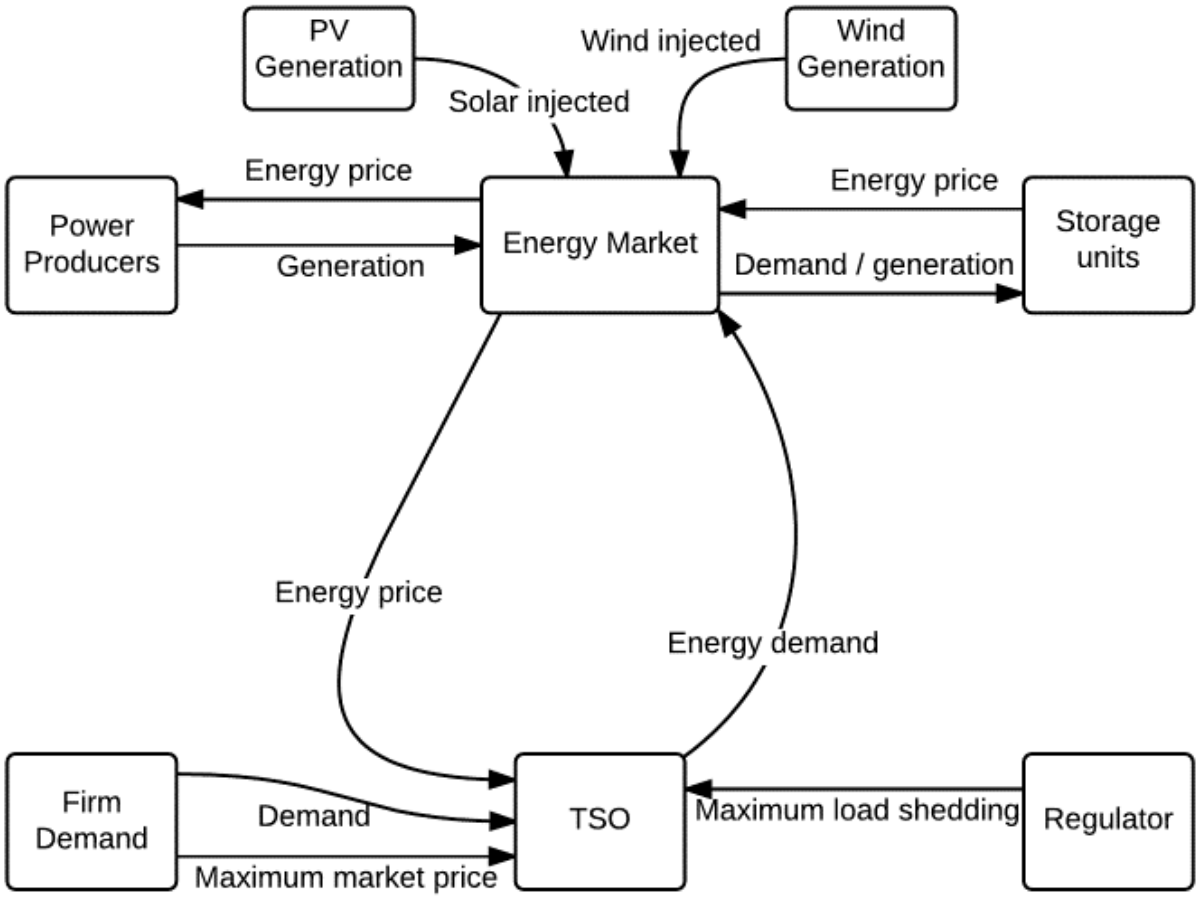
Method

•Renewable production is injected into the system



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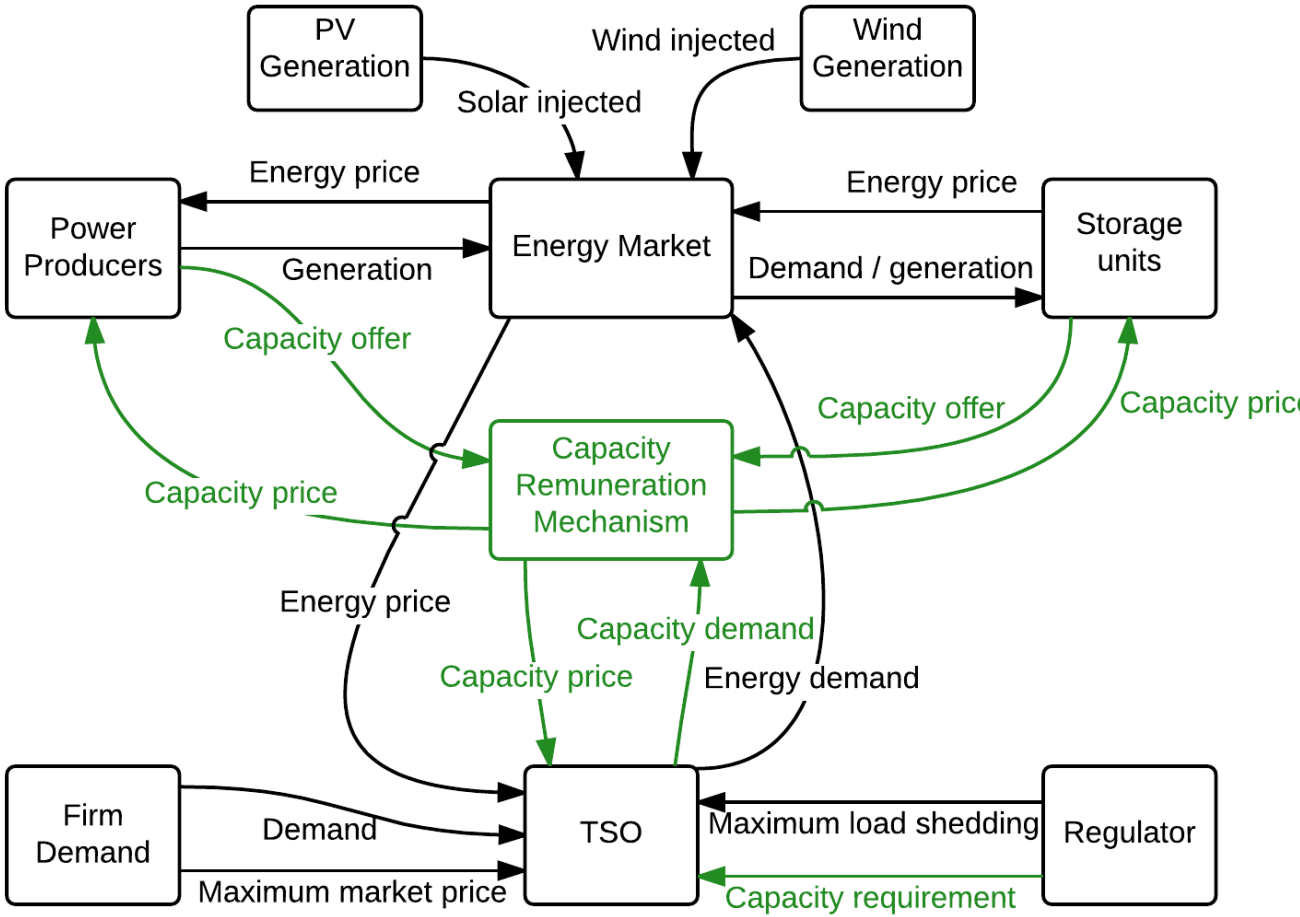
Method

- Introduction of capacity remuneration mechanism
- Another market coupling between market participants



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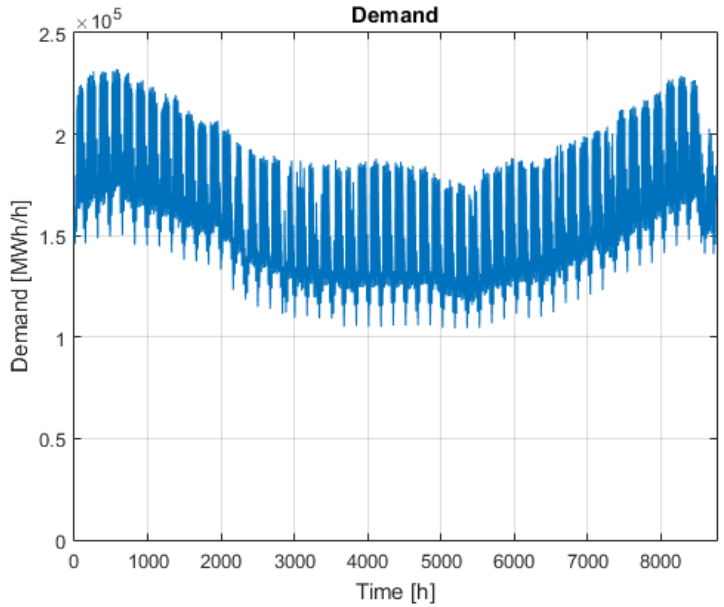
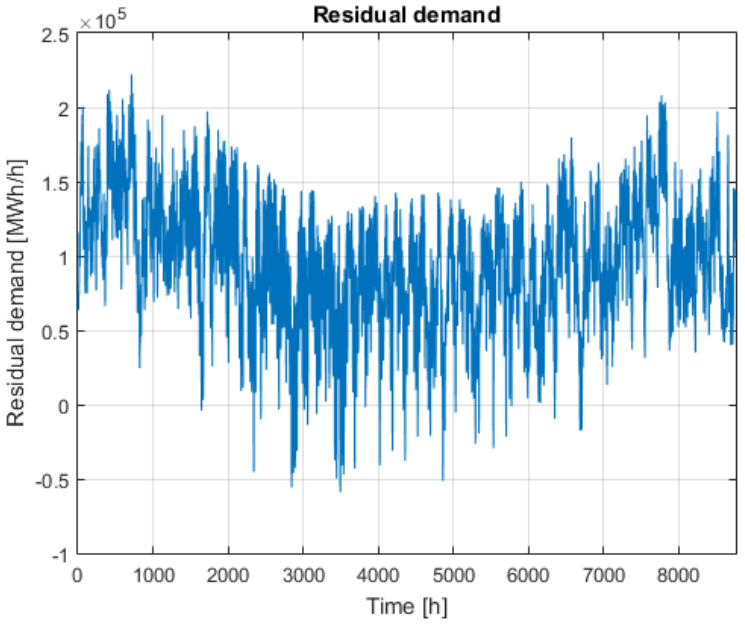
Data Input

- High RES scenario of the northern European power system: ENTSO-E Vision 4.
- Renewable share: 41.5% of total demand
- **Four thermal technologies with variable and fixed costs:**
- Nuclear, Coal, CCGT and OCGT.
- **Two storage technologies with fixed costs and efficiencies:**
- Norwegian PHES and Lead-acid batteries.
- PHES includes cost of HVDC cables
- **Optimal installed capacities and operation each hour is determined by the model**





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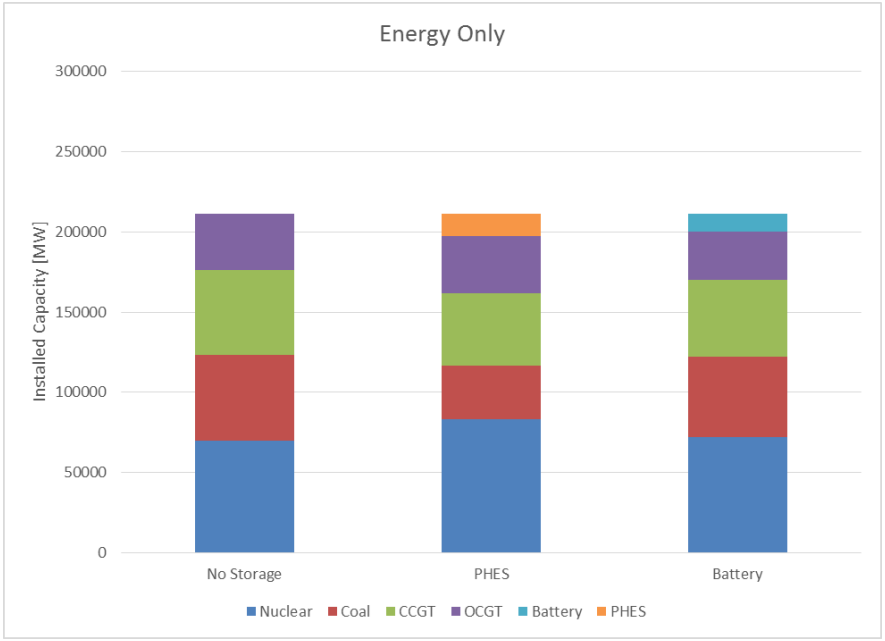
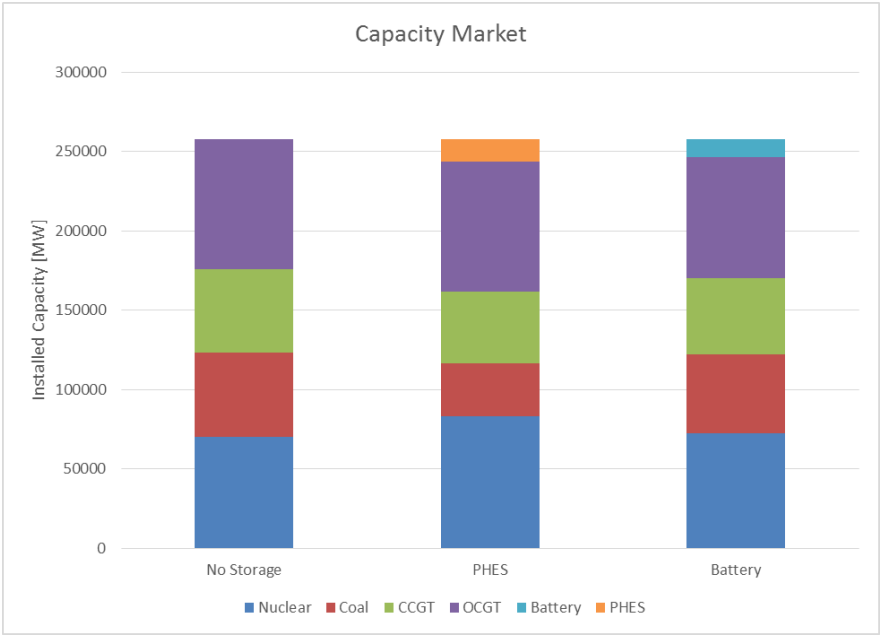
Results: Installed Capacity

- Introduction of Norwegian PHES increase nuclear power capacity by 18.8% while CCGT and Coal is reduced
- Battery reduces the OCGT capacity
- The additional capacity with a capacity market is OCGT





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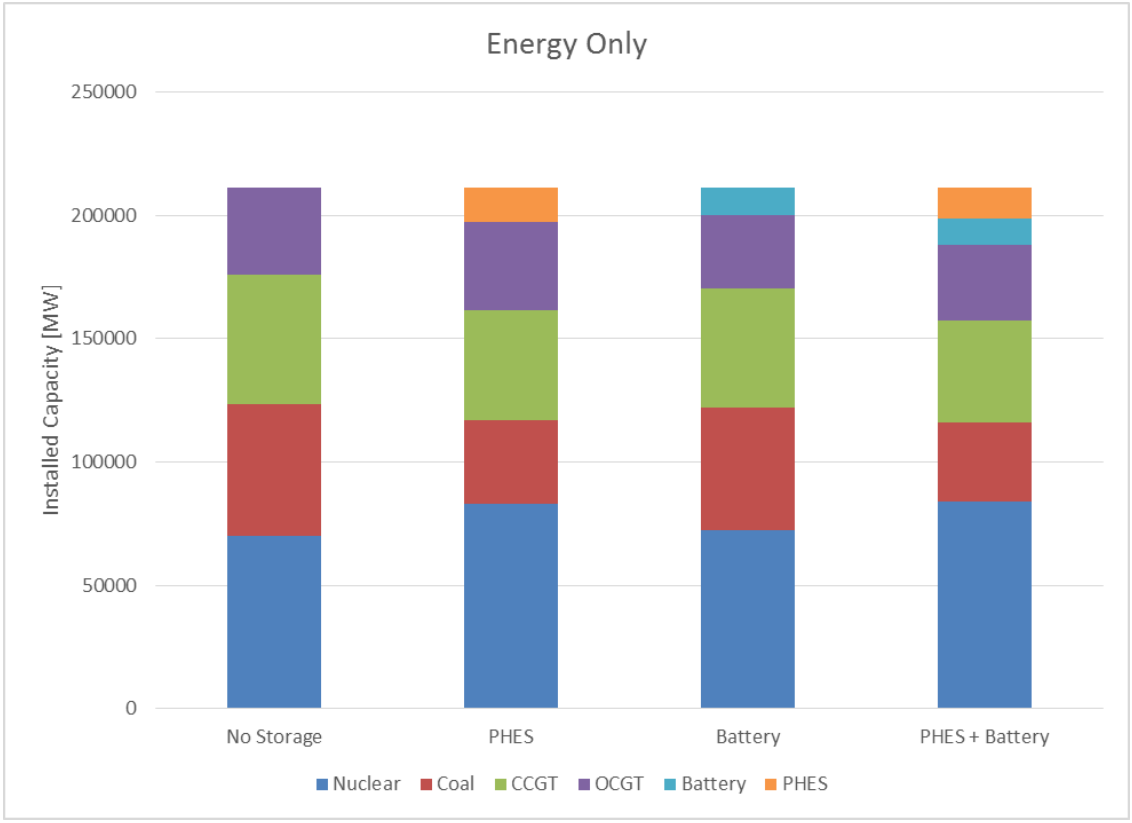
Results: Installed Capacity

- PHES + Batteries in the same system: Nearly the same installed capacity.
- Increased base load capacity.
- This suggests that both technologies are needed in the system.



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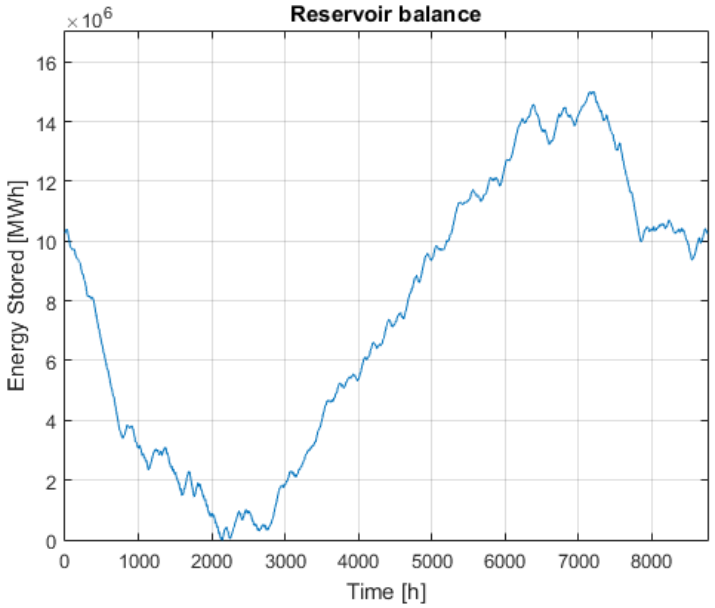
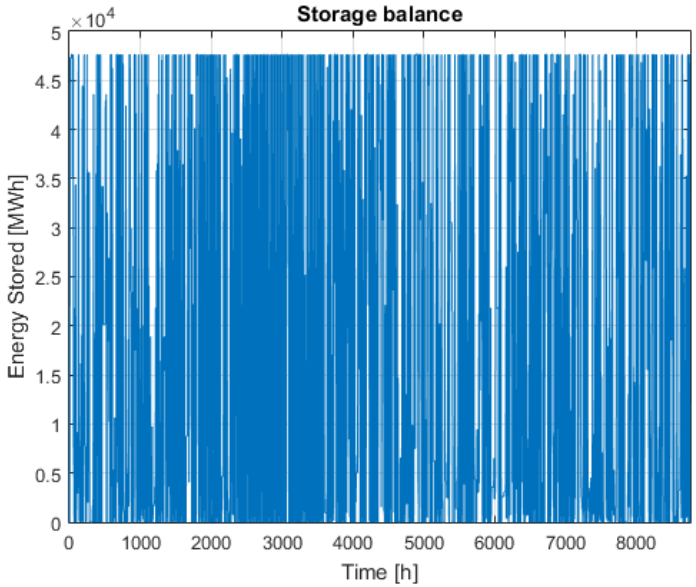
Which storage technology?

- There is no universal storage technology.
- Mix of technologies necessary.
- Computation with both technologies simultaneously suggests a need for several technologies.





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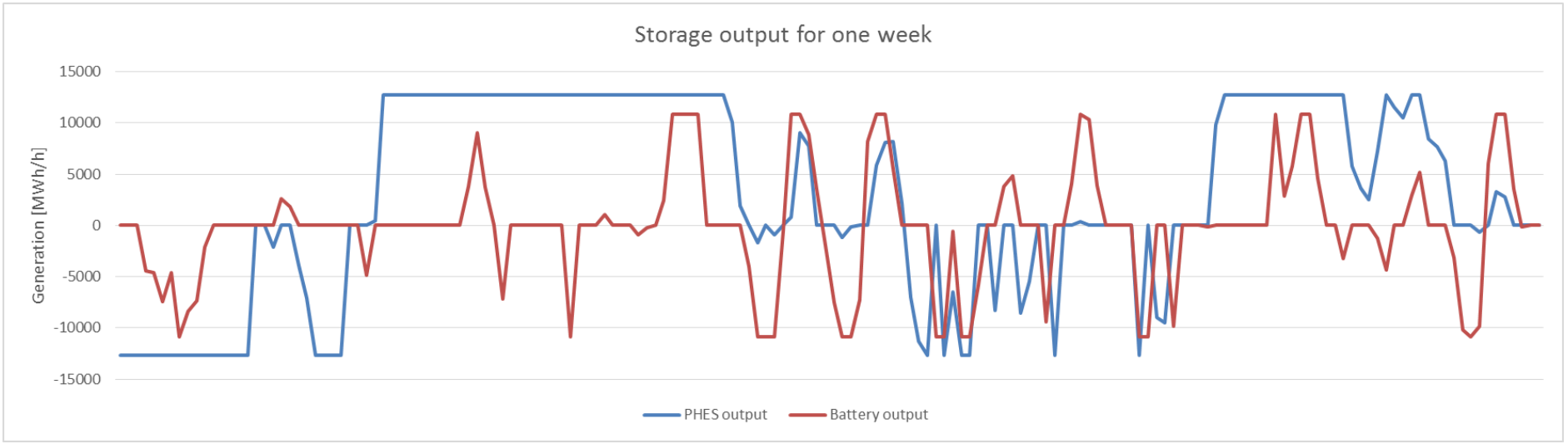
Which storage technology?

- PHES need a bigger price difference in order to profit due to lower efficiency.
- Batteries can store less hours due to high energy capacity costs



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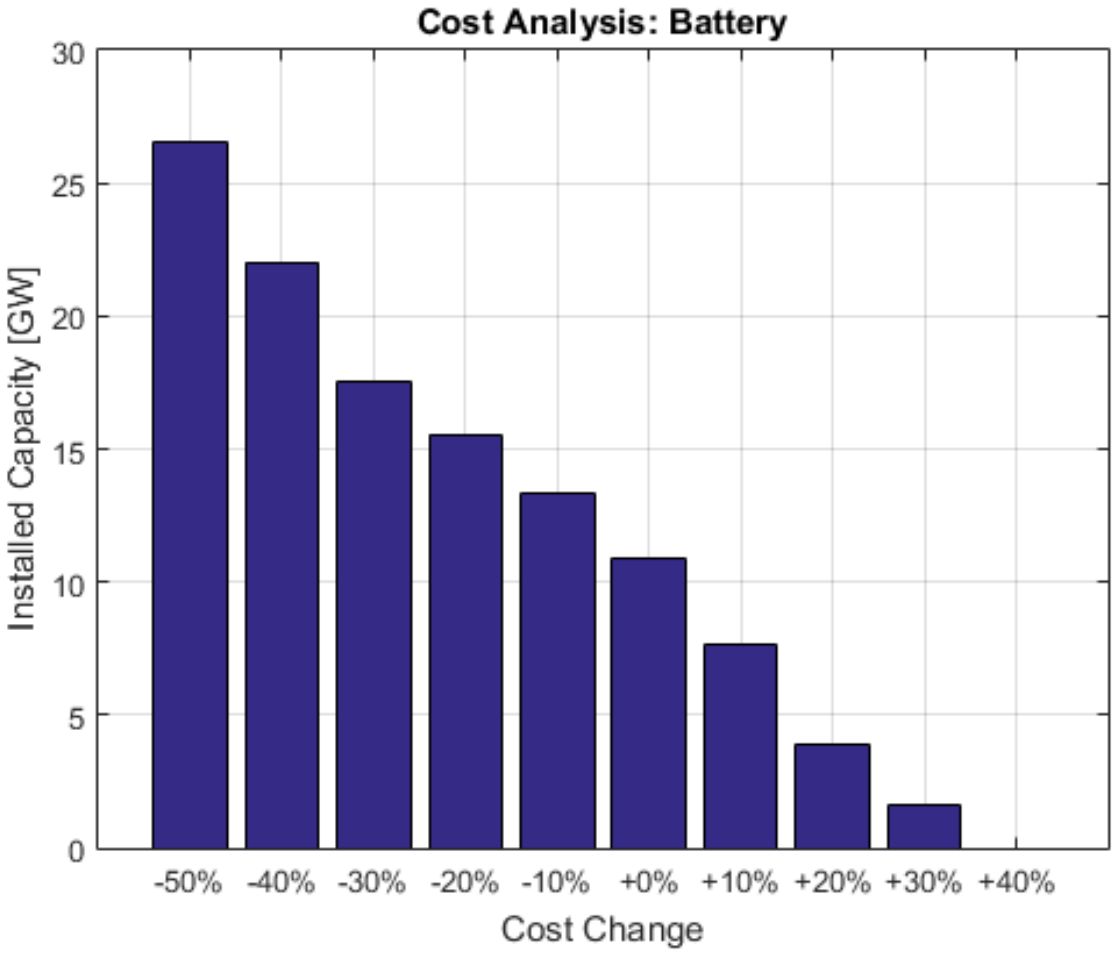
Sensitivity to costs

- **Reference annual costs (0%):**
- Converter cost:
- 25 901 EUR/MW
- Capacity cost:
- 6 475 EUR/MWh
- **A cost increase of 40% resulted in zero installed capacity**



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Questions?

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