Large Scale Energy Storage & Conversion in a Renewable Energy System

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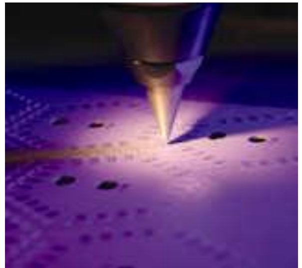
R&D programmes of ECN

Policy Studies



Energy Engineering

Environment

Energy Efficiency & CCS

Wind Energy

Solar Energy

Biomass

Storage & Integration of Renewables

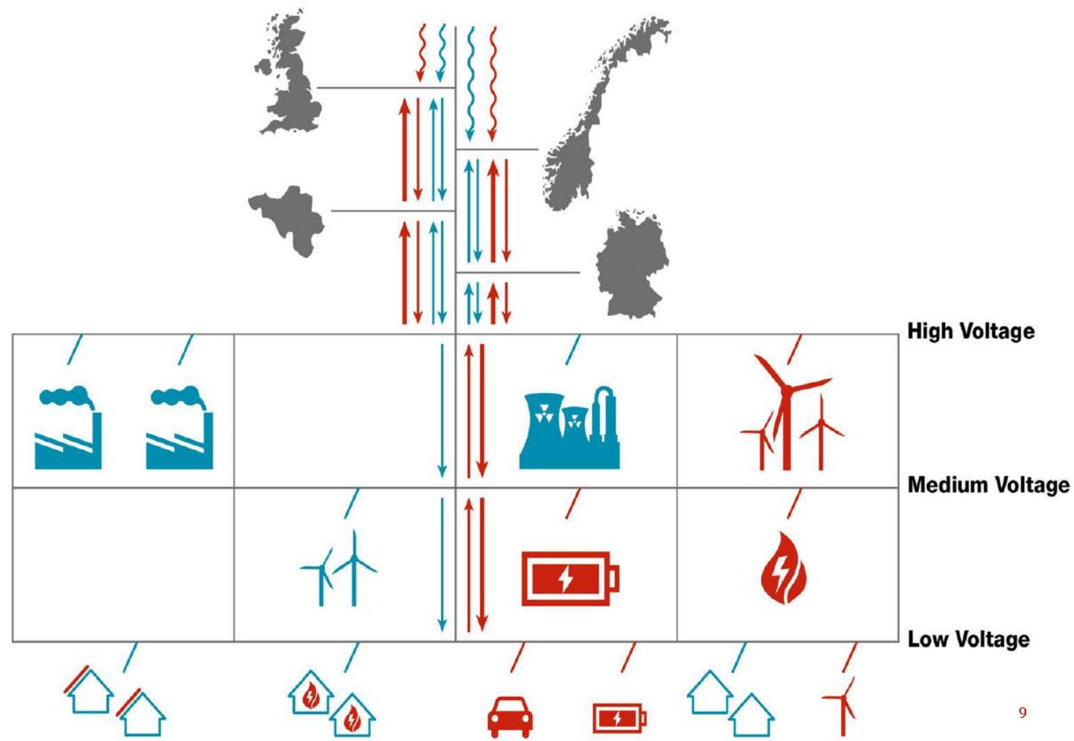
Outline

- Energy system challenge
- Flexibility options
  - Large-scale electricity storage
  - Electricity conversion in chemical sector
- ECN technology example
- Conclusions

Paradigm shift in the electricity system

From top-down:
- Demand driven
- Supply matches demand

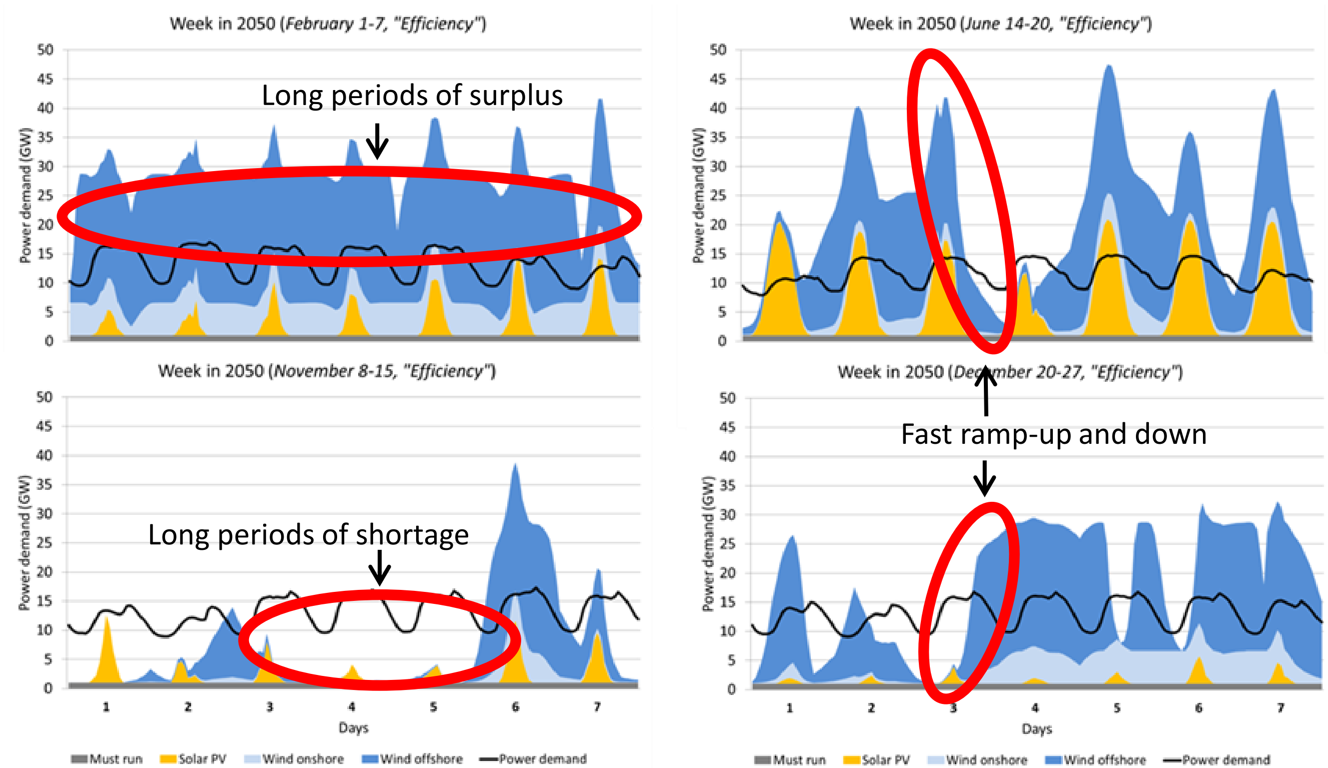
To more complex:
- Supply at all levels
- Intermittent supply
- More flexible demand



Source: Tennet

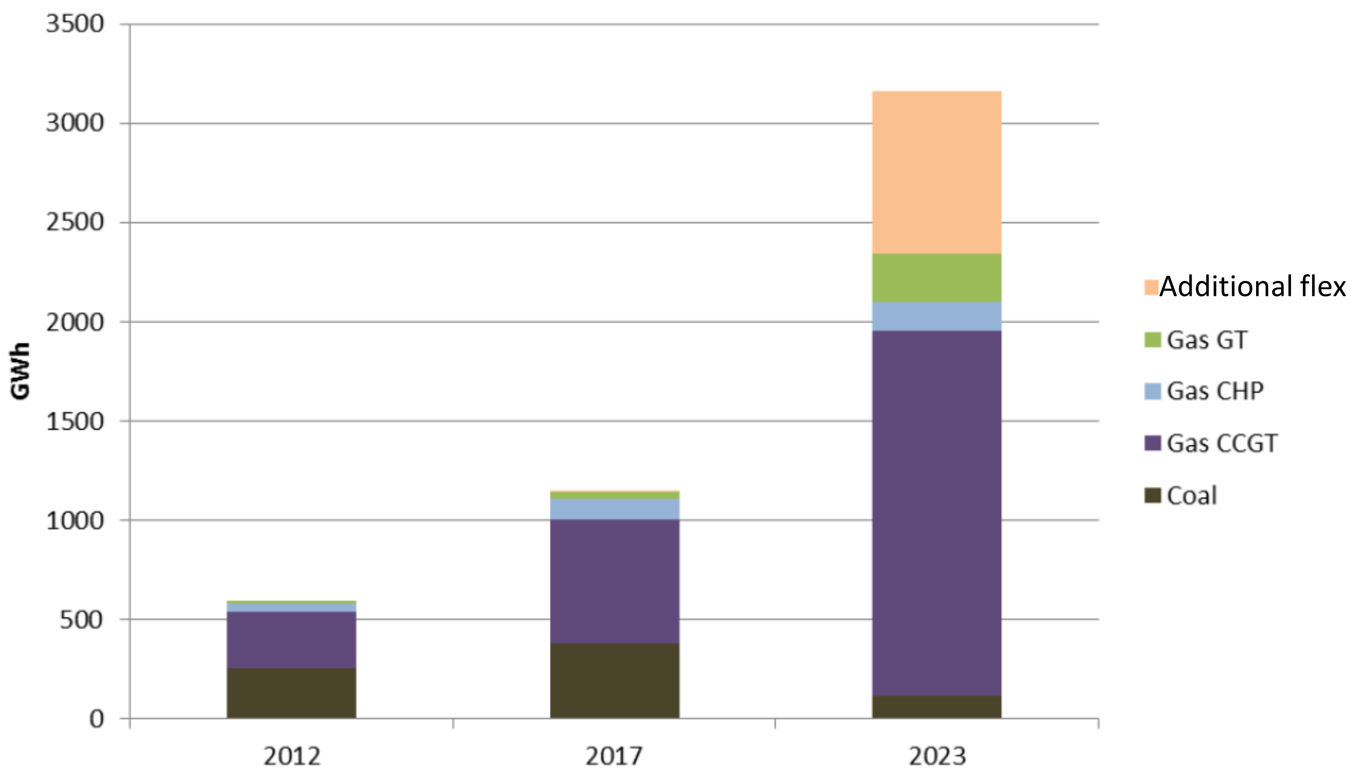
Challenge:
more renewables, lower predictability

Electricity balance per hour for 2050, selection of weeks



Source: HyUnder / P2G System study

Demand for upward flexibility NL 2023



*Demand for flexibility mainly caused by forecast error of wind energy

Key take-aways from scenario studies

- Reliability and affordability are imperative, next to sustainability
- Towards 2030 and 2050 a strong increase in system flexibility needed for:
  - Time-shift: balancing of supply and demand on daily, weekly and annual basis
  - Rapid response to ramp up and down at changes of weather conditions
- A larger contribution of intermittent renewables leads to surplus as well as shortage of supply:
  - Storage is a short-term solution for the surplus, a *sink*
  - Storage will become a true energy buffer in the long run, *sink and source*
- Backup power capacity similar to the current fossil fleet is needed, despite its lower utilization

Sources of flexibility - constrains

Flexible supply	Demand response	Interconnection	Energy Storage & conversion
			

Constrained by … declining economics of fossil power plants

… capacity that can be shifted by end-user

… rate of installation and ‘economic distance’ of transport

… CAPEX and utilization

Large-scale storage & conversion

Focus of this study

- Business case for large-scale energy storage solutions in the day-ahead electricity market and / or the balancing market

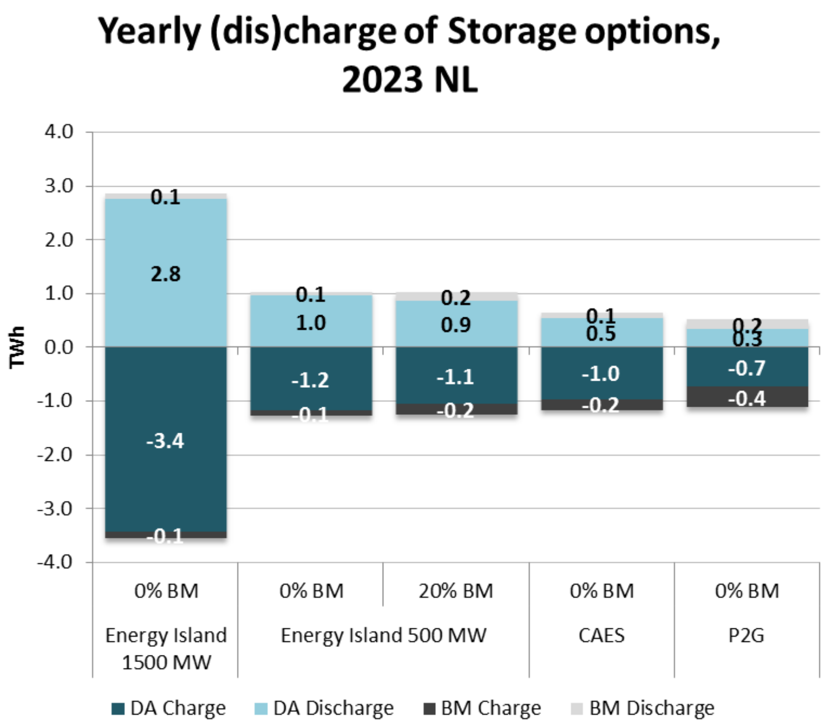
- Key question: what are the potential revenues from these two markets for three particular types of storage solutions in the year 2023?

Energy Island

Power-to-gas (P2G)

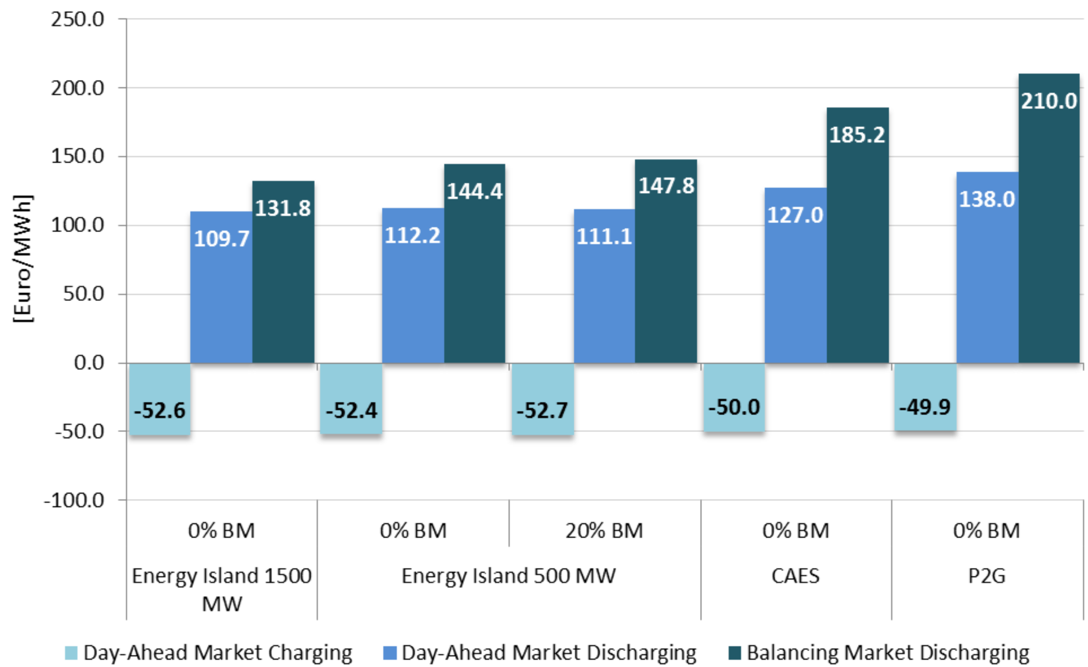
Compressed Air Energy Storage (CAES)

Yearly charge/discharge



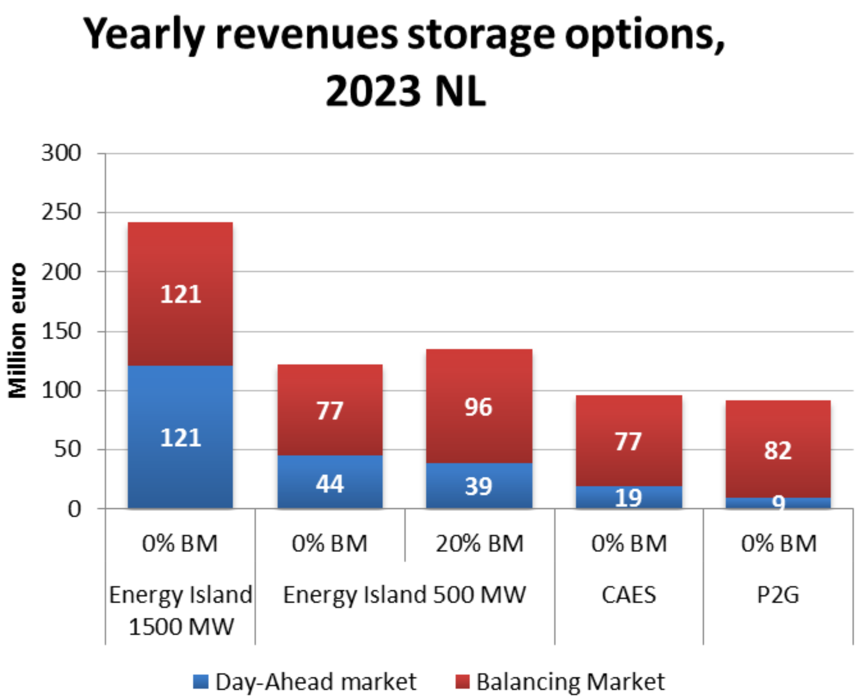
- The more efficient the storage option
  - the better it can compete in the day ahead market
  - the higher its utilization (irrespective of capacity)
- In the balancing market efficiency levels are less important
  - balancing capacity is scarce, so less competition
- When a certain capacity is reserved for the balancing market, (dis)charge shifts from the DA market to the BM

Price received/paid for (dis)charging



- *Efficiency effect*: higher efficiency means higher utilization; higher average prices paid when charging due to higher total charge and lower prices received when discharging
- *Capacity effect:* in line with efficiency effect

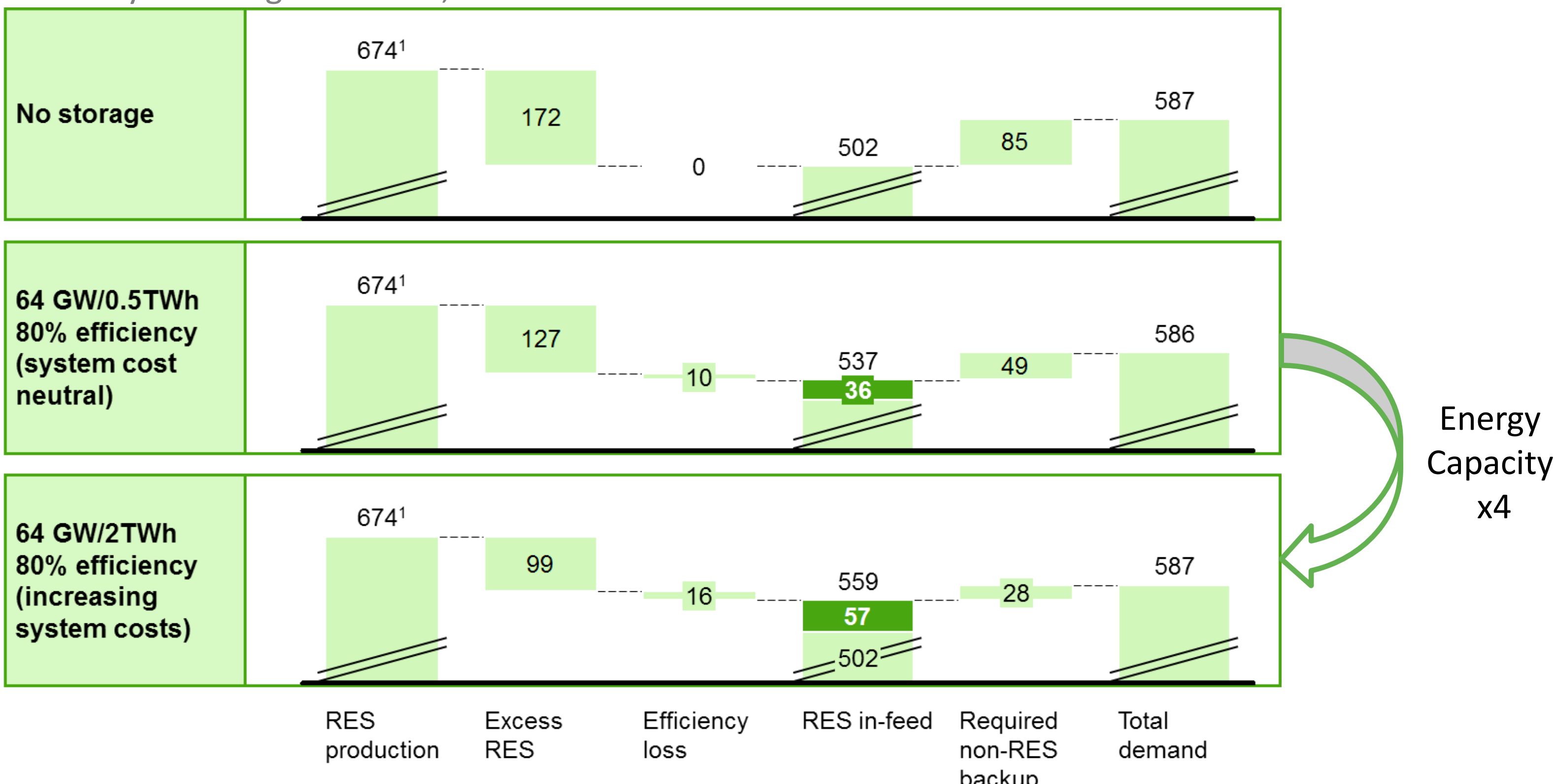
Storage revenues and scale



- Reserving 20% of Energy island capacity for BM, additional revenues can be gained (+10%)
- In the BM revenues are relatively high due to higher e-prices
- Comparing Energy Islands of 500 and 1500 MW Energy island, revenues are only double

Storage economics & non-RES backup

Germany 2050 High-RES case, TWh

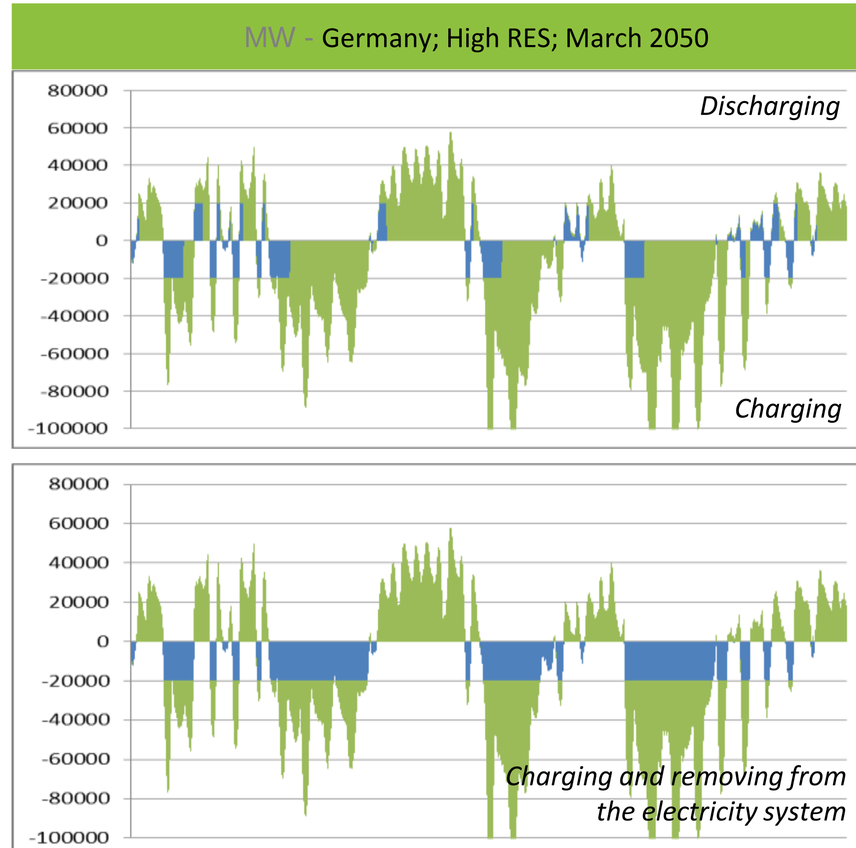


1 Of which 508 TWh VRE, 166 TWh other

Source: FCH-JU 2015

Utilization of P2P storage vs. electricity conversion options

- P2P storage can only use part of the excess electricity
  - Energy and power capacity are limited
  - Economic capacity does not capture all surplus
- Conversion options (P2X) utilize all surplus hours
  - Only power capacity is limited
  - Storage of product (H_2, heat, chemicals) should be at near zero cost



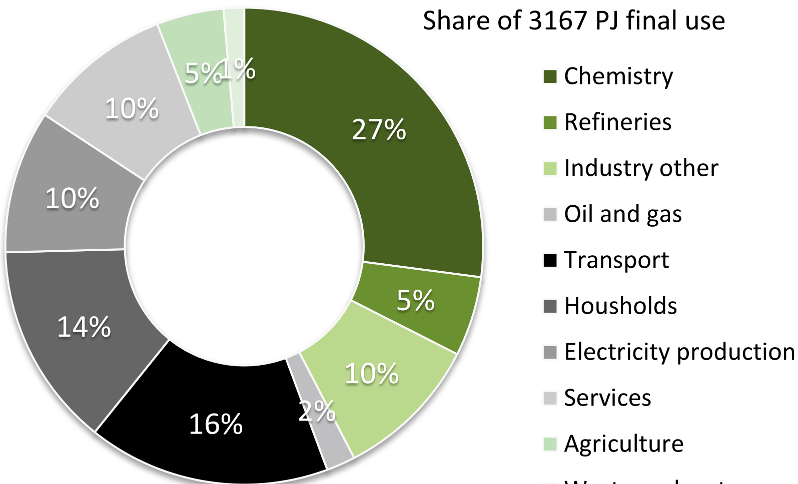
Source: FCH-JU, 2015

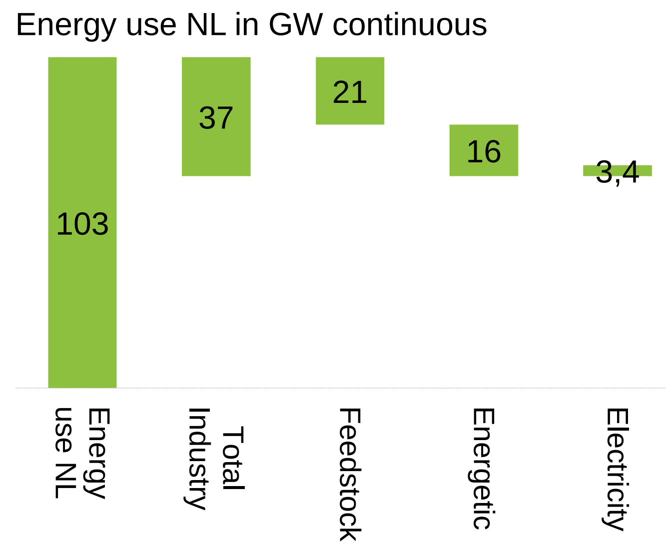
Key messages

- All studied large-scale energy storage options generate substantial revenues on the day-ahead electricity market and balancing market in 2023
  - Energy island of 1500 MW: M€ 242 / y
  - Energy island of 500 MW: M€ 122 – 134 / y
  - CAES of 500 MW M€ 96 / y
  - P2G of 500 MW M€ 91 / y
- Energy efficiency and size of any storage facility are key in determining potential revenues.
- Reserving capacity for the balancing market leads to extra profit (10% in this example)
- Caveat: electricity market factors may impact revenues and should be considered in future analyses

Electricity conversion: Large-scale DSR in industry

Energy use in the NL Industry





Year	Source	$GW_{eq\ cont}$	$GW_{installed}$
2013	Total electricity generated	13.5	30
2013	renewable electricity	**1.4**	
2030	Total electricity generated	14.1	
2030	renewable electricity (53%)	7.5	
2030	intermittent solar/wind (87%)	**6.5**	**26**

Source: ECN Nationale Energieverkenning, 2014

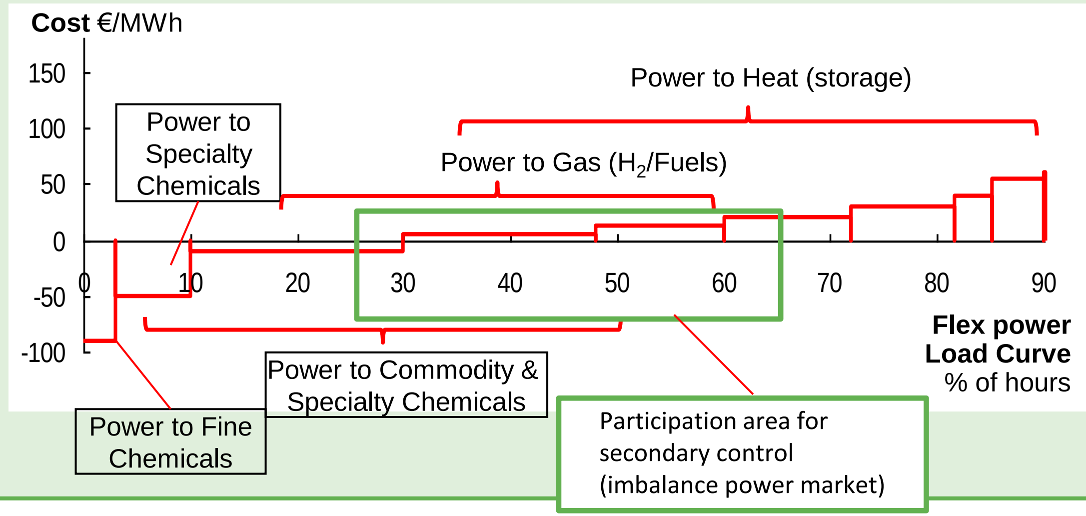
Electrification technologies

Illustrative cost curve of demand-side response in chemistry

Methodology

Cost curve of electrification options in 2040 -2050

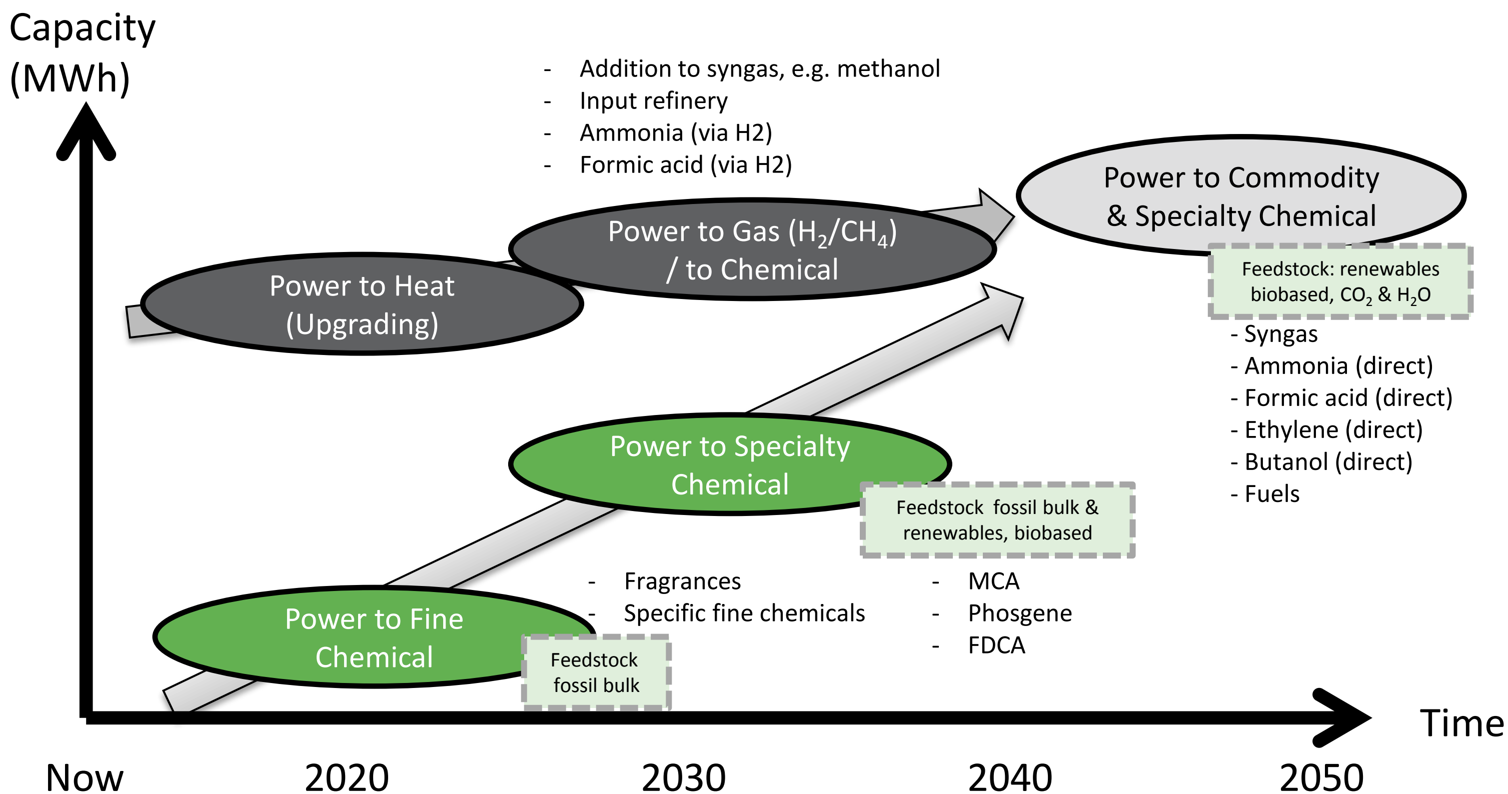
Assumptions
- High CO_2 price
- High volatility power markets
- Electricity storage mature technology



- Economics of demand-side response options determine their dispatch strategy:
  - Power to fine and specialty chemicals - mainly base-load power off-take.
  - Power to heat - wide range of profitable application (e.g. E-grid management, imbalance market or day ahead options).
  - Power to gas – Imbalance market, intraday and day ahead markets.

Source: ECN & TNO, 2015

High level Road Map of Electrification of Chemical sector



Source: ECN & TNO, 2015

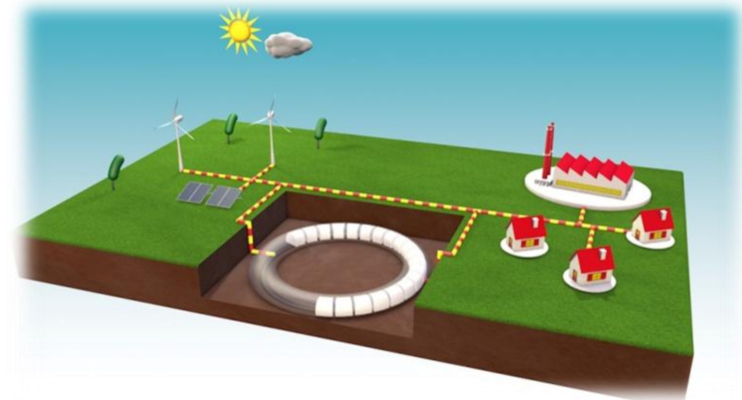
Technology example: Energy Train

Energy train

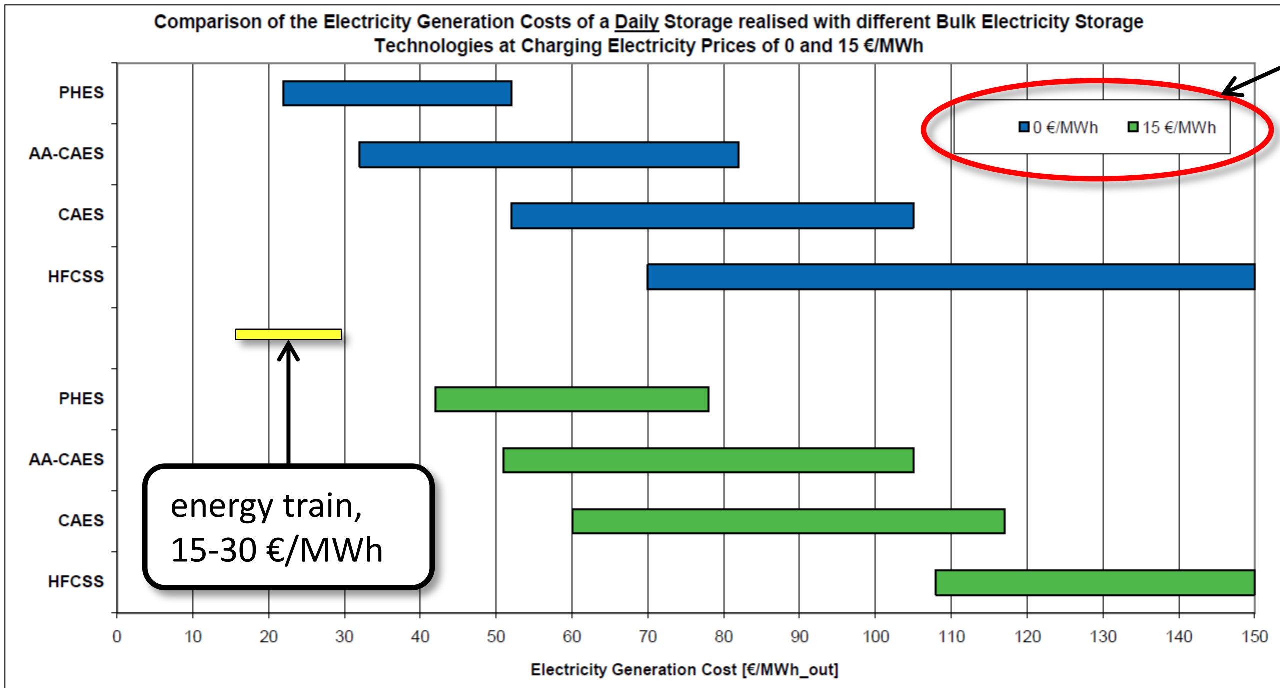
- Movie Energy Train

The Energy Train main specs

- Power:
  - 2,5 GW
  - 8 h charge/discharge
- Size:
  - Ring diameter: 5 km
  - Tunnel size: 5 m diameter
  - Moving mass: 600 000 tons
  - Speed: up to 500 m/s
  - Acceleration:
    - max 10 g lateral
    - max 0.03 g tangential
- High efficiency:
  - Friction loss: <2%/day
  - Electro-mechanical propulsion
  - Maglev suspension
  - Vacuum



Storage cost and e-price sensitivity



0 €/MWh unlikely with storage present, 15€/MWh is low estimate

energy train less sensitive to e-price, due to high round-trip efficiency

Figure 18: Comparison of the electricity generation cost of a daily storage realised with different bulk energy storage technologies at two different charging current prices (Source: Wietschel, 2011)

source: www.store-project.eu

Conclusions

- Growing intermittency of power production leads to higher volatility in the market
  - Business cases for additional flexibility options become viable in the short run
  - Need for time shift as well as fast response flex-options
- Market for P2P storage has an upper bound: revenues per unit of capacity diminish to scale
- Utilization of conversion options can be much higher than storage options
- All examples assume a level playing field for all flexibility options
  - The role of storage needs to be defined
  - The role of different stakeholders needs to be redefined
  - Cost of imbalance to be put at the source of intermittency

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