European Energy Markets – Lappeenranta, 7 June 2023

Long Duration Flexibility – Key to the Green Transition of the Power System

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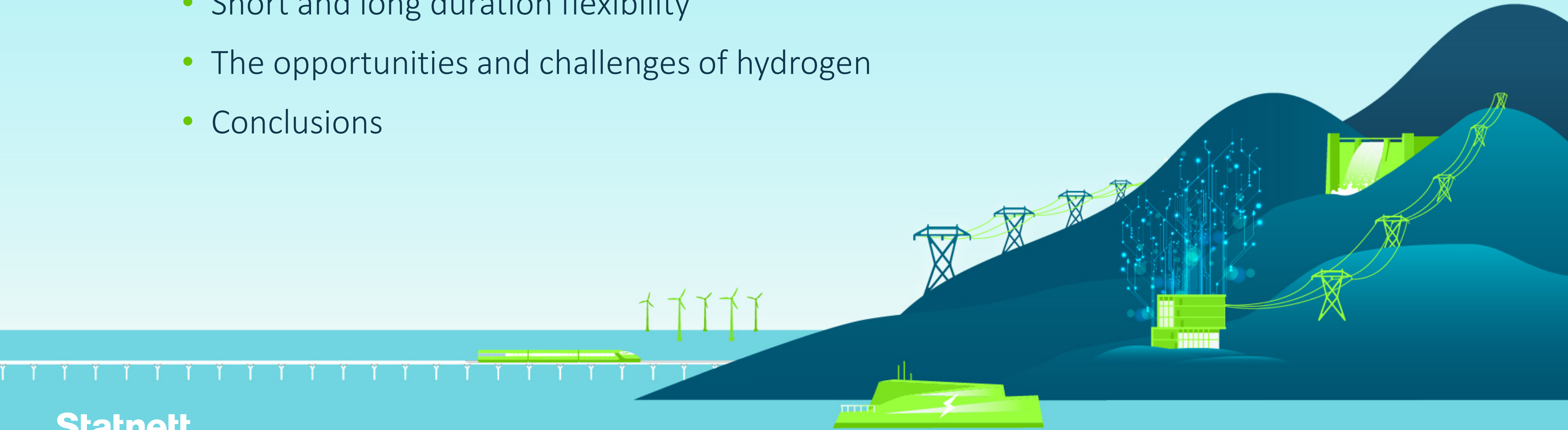
Overview

- ENTSO-E Vision for a Power System for a Carbon Neutral Europe
- The impacts of huge amounts of weather dependent generation
  - Too little and too much
- Short and long duration flexibility
- The opportunities and challenges of hydrogen
- Conclusions



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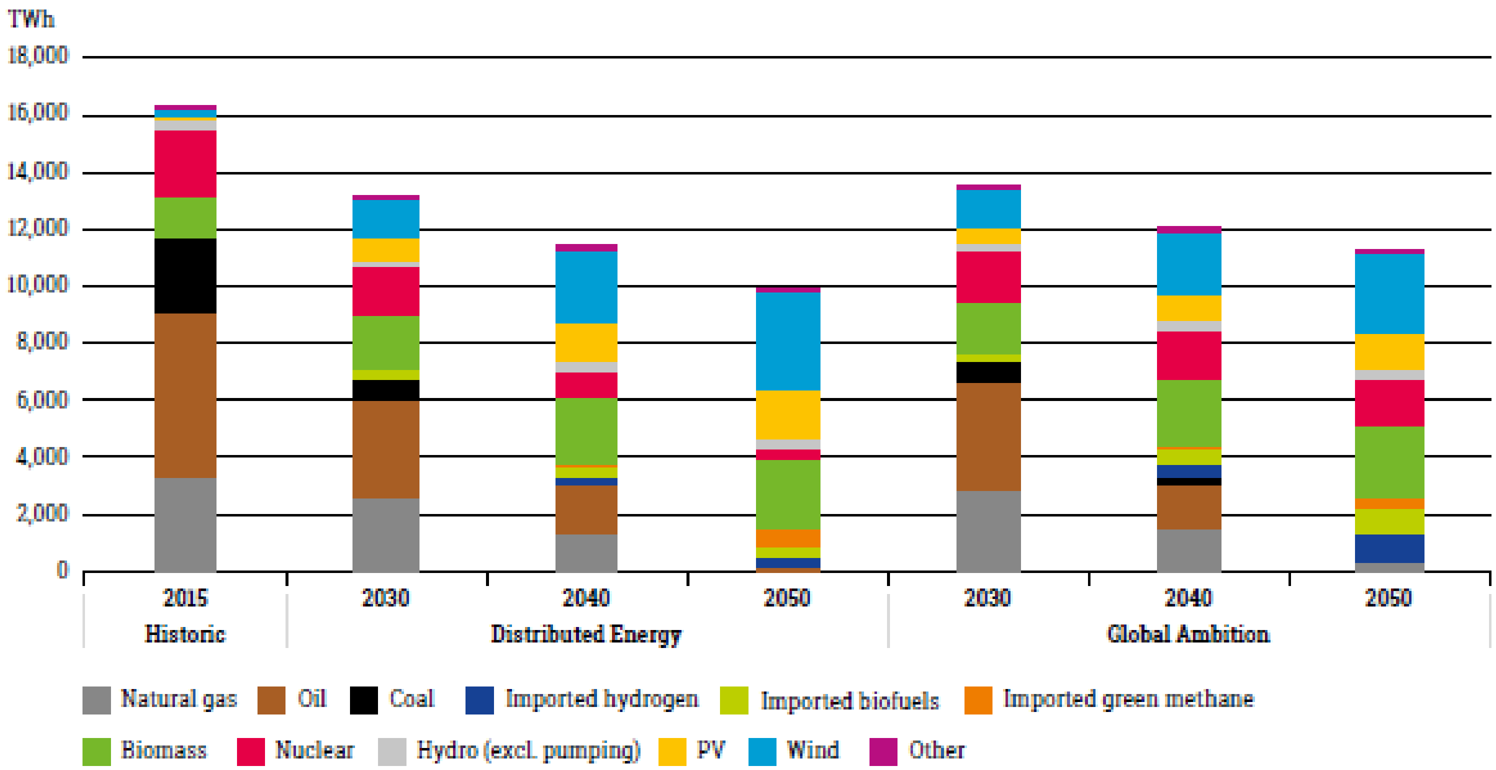
ENTSO-E Vision for a Power System for a Carbon Neutral Europe*

- Three key elements
  - **Carbon neutral** energy sources
  - System **flexibility** resources
  - The **power grid**, enabling a fully integrated European energy Market
- The future power system in Europe will be
  - A **System of Systems**
  - More **European** and more **Local**
- A power system for a Carbon Neutral Europe is within our reach, subject to
  - The development of significant **short and long duration system flexibilities**
  - **Operation** of the system that will rise up to the challenge of a highly dynamic System of Systems
  - A regulatory framework, plus planning and permitting procedures that will facilitate **the timely deployment** of the necessary investments
  - A **market design** as a key enabler, that must evolve to allocate **value** where and when it will be most needed for the energy system, while reflecting different **consumers**' needs and preferences.

*https://vision.entsoe.eu/

What will the energy future look like



Primary energy supply in the two COP 21 scenarios (for energy and non-energy use) for EU27

Source: TYNDP 2022 Scenario Report (ENTSO-E/ENTSO-G, April 2022)

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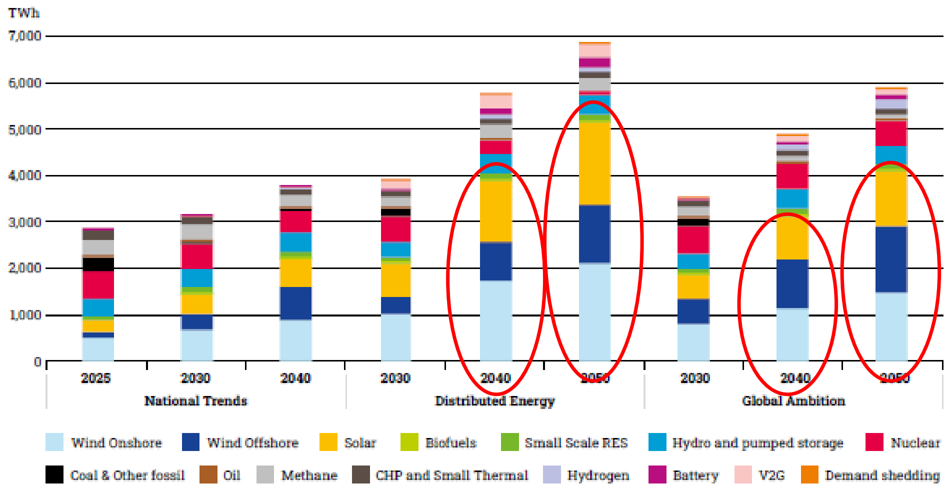
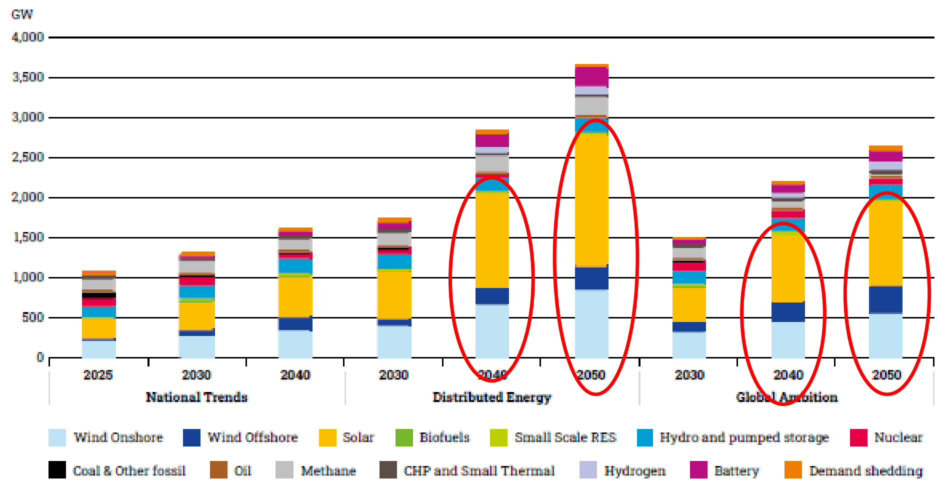
And what does this mean for the power system?



Power generation mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)



Capacity mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

- Wind and solar PV will provide very high shares of generation already in 2030
- But the wind is not always blowing, and the sun not always shining…
- Moreover, quite often they produce *way too much*

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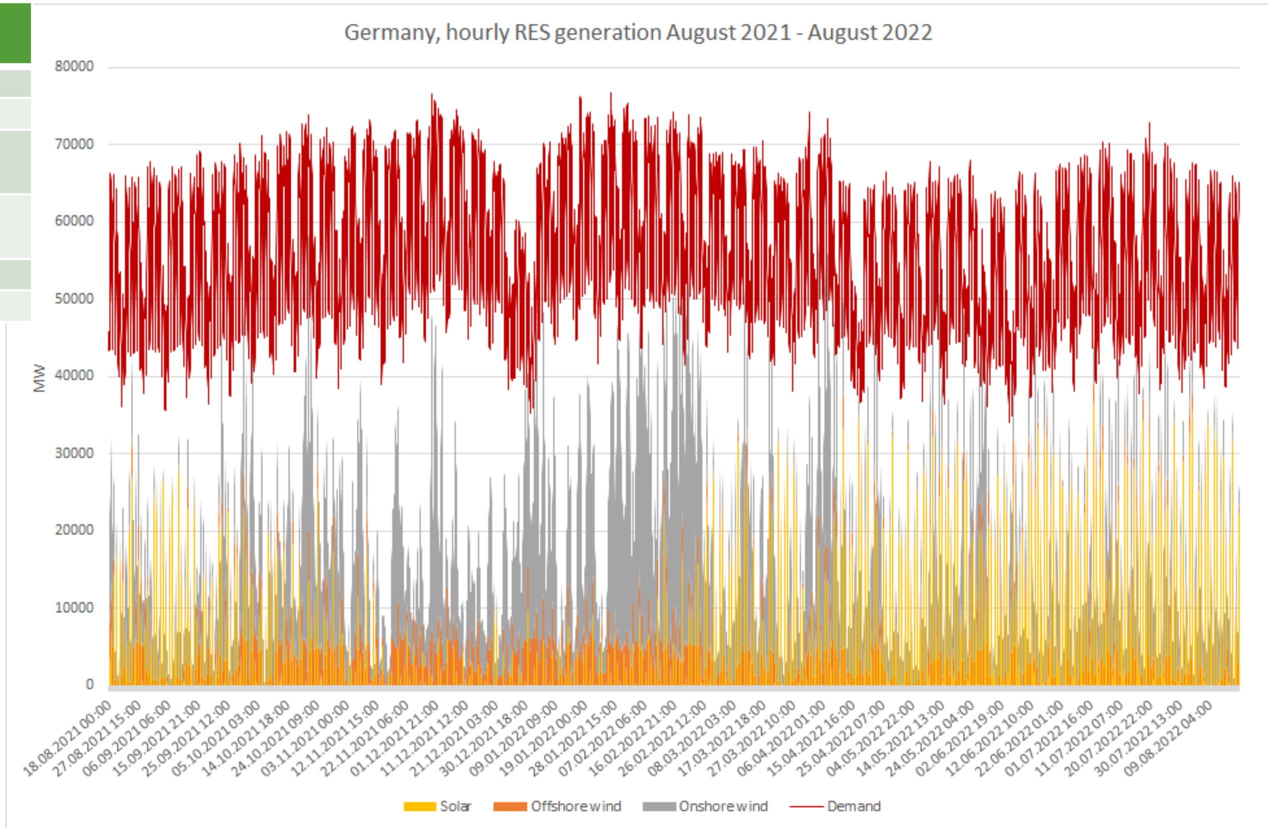
Impact of high shares solar and wind

Simple exercise using the German power system

	Peak (GW)	Installed (GW)	Total (TWh)
Demand	76,8	-	490
Solar PV	38,1	59,0	54
Offshore wind	7,2	7,8	25
Onshore wind	44,0	56,3	100
Total RES	59,4	123,1	178
RES share (%)	-		36,3



- RES share 36.3%
- Disregarding grid congestion
- No curtailment assumed
- Total RES production never exceeds total demand
- But in the real world still hours with negative prices

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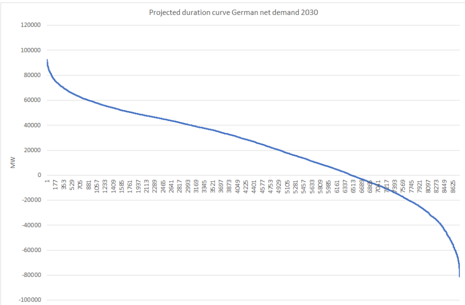
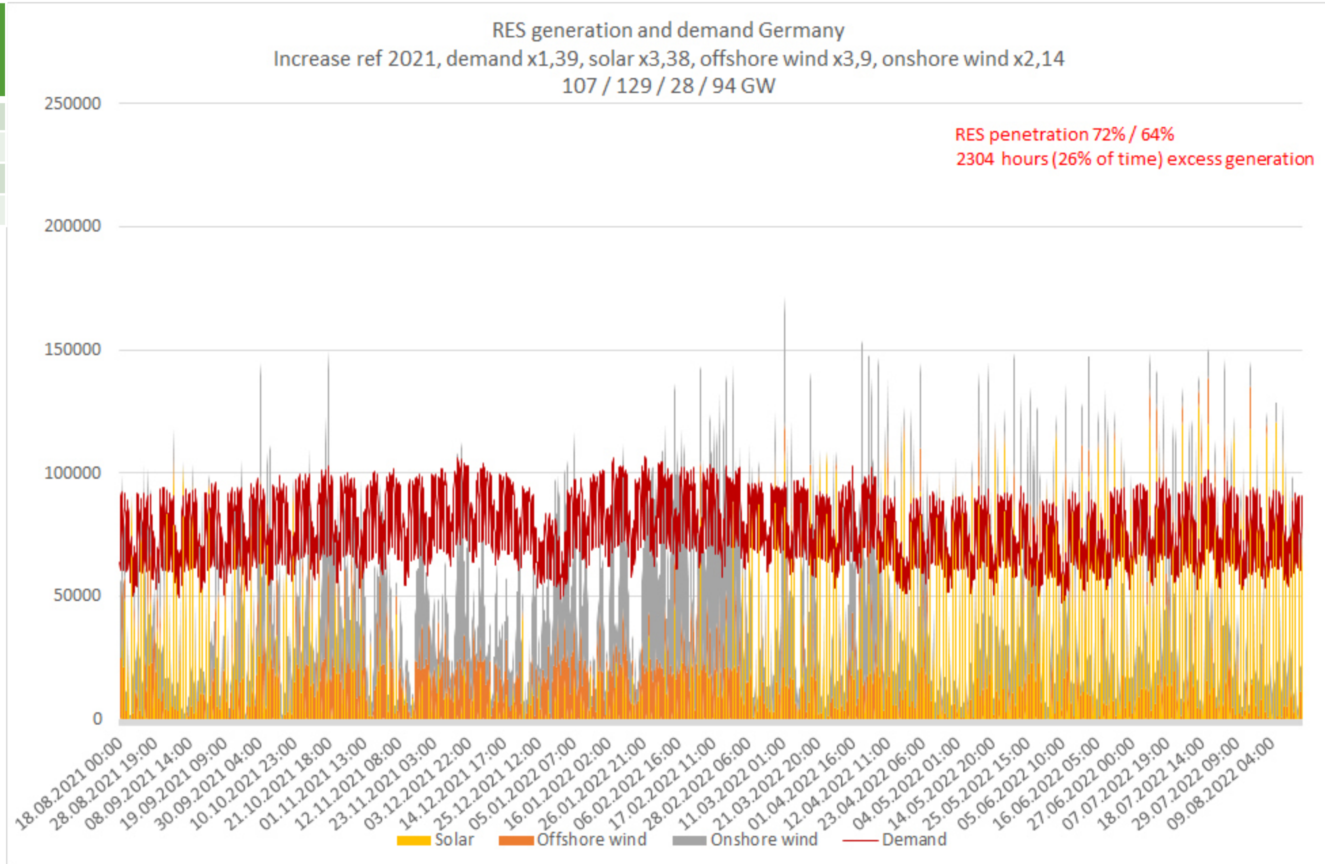
Projected German power system 2030

	Estimate	Projected Peak (MW)
Demand (TWh)	680	-
Solar PV (MW)	200	129
Offshore wind (MW)	30	28
Onshore wind (MW)	120	94

- Projected 2023*
- RES share 72% or 64% when subtracting excess generation
- 52 TWh excess RES generation, 11% of total
- 2304 hours of excess generation

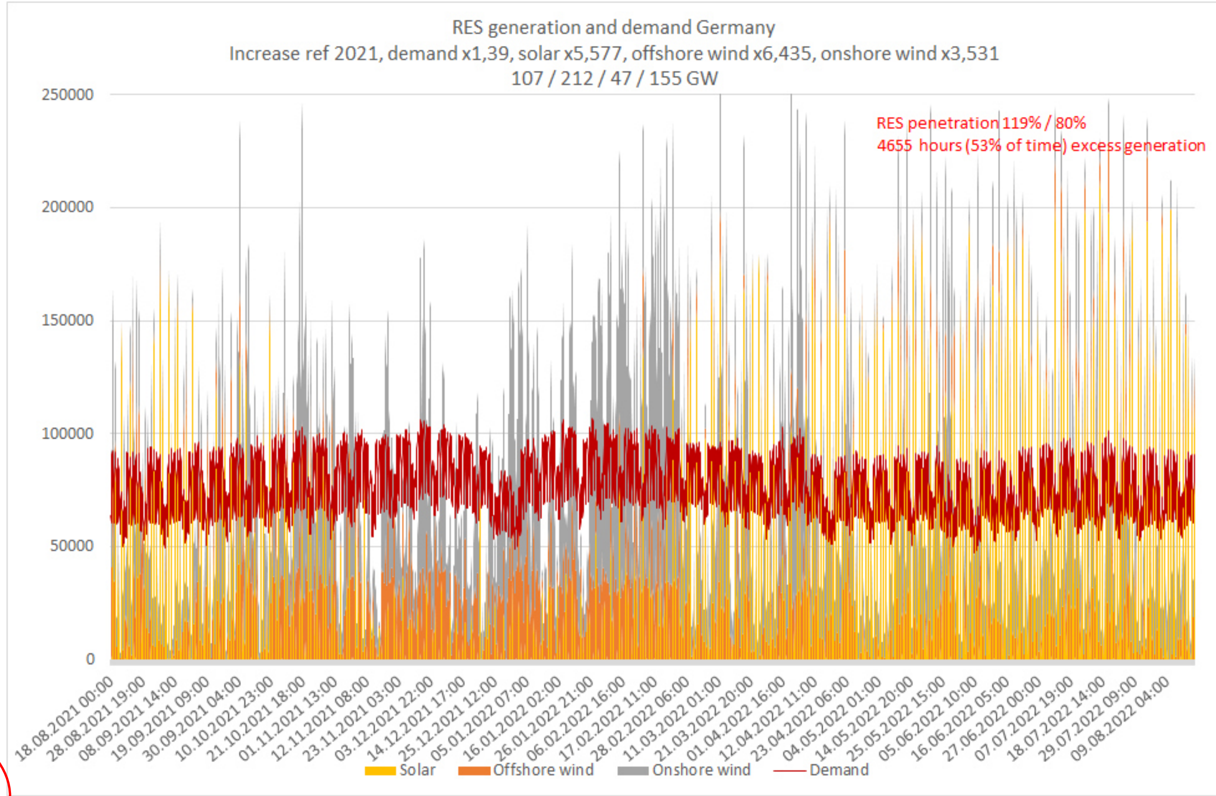




*https://www.energy-charts.info/charts/installed_power/chart.htm?l=de&c=DE&year=2022&chartColumnSorting=default
https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/112521-german-coalition-plans-for-480-540-twh-renewables-by-2030-to-exit-coal

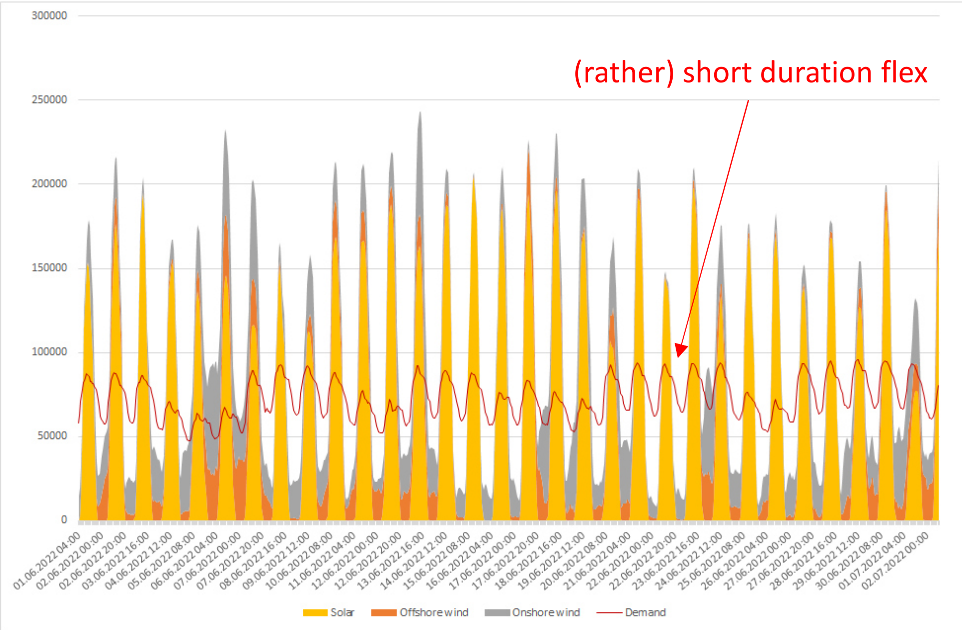
And what about even higher RES shares?

- Scaling up to 80% RES share of final demand
- Total RES generation is 119% of total demand
- Excess RES generation: 265 TWh
- RES could have covered total demand if 50% of excess generation was recovered as usable electricity

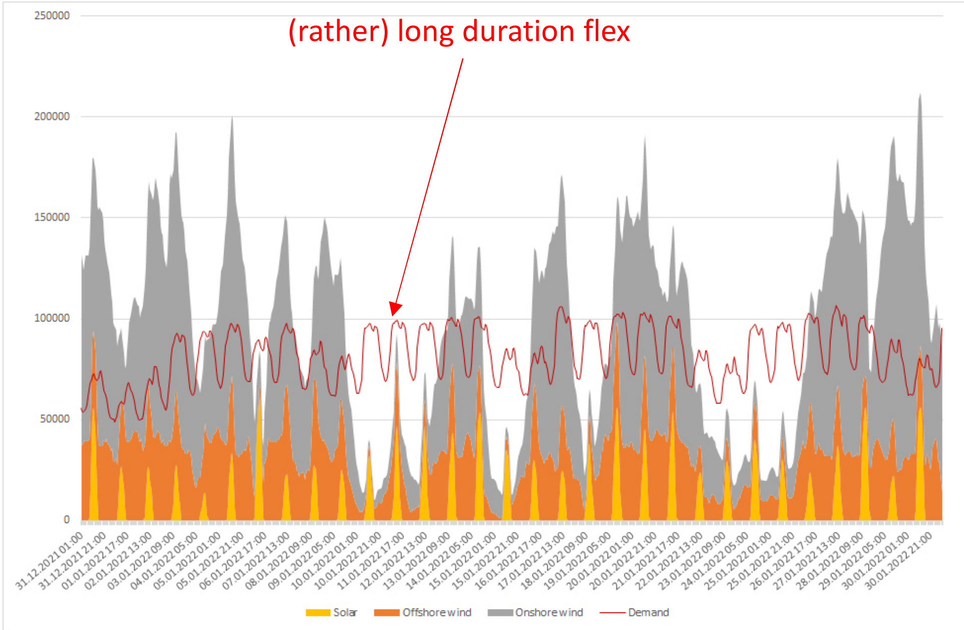


What to do with this?

Monthy results

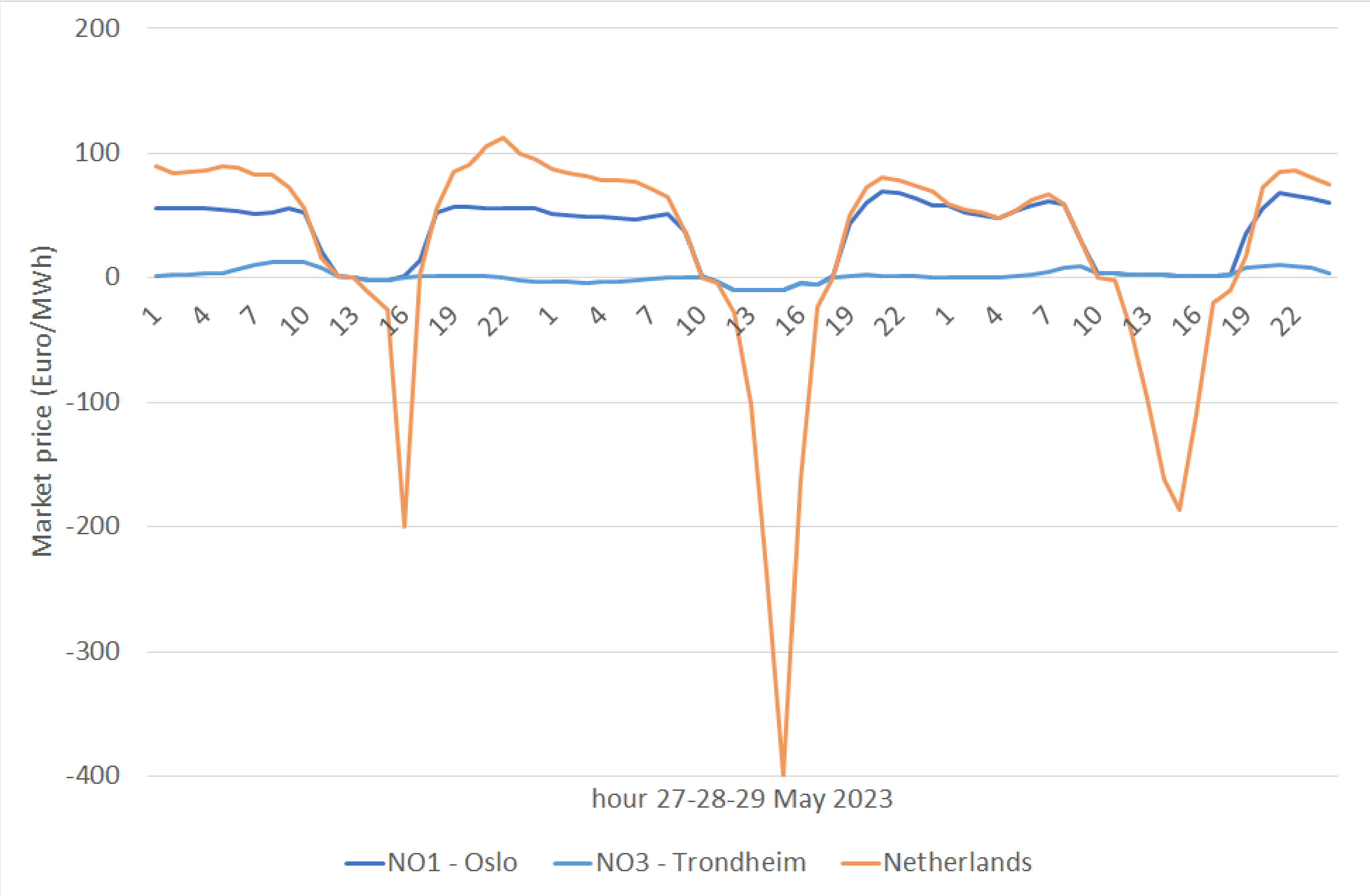


Resulting RES and demand in June

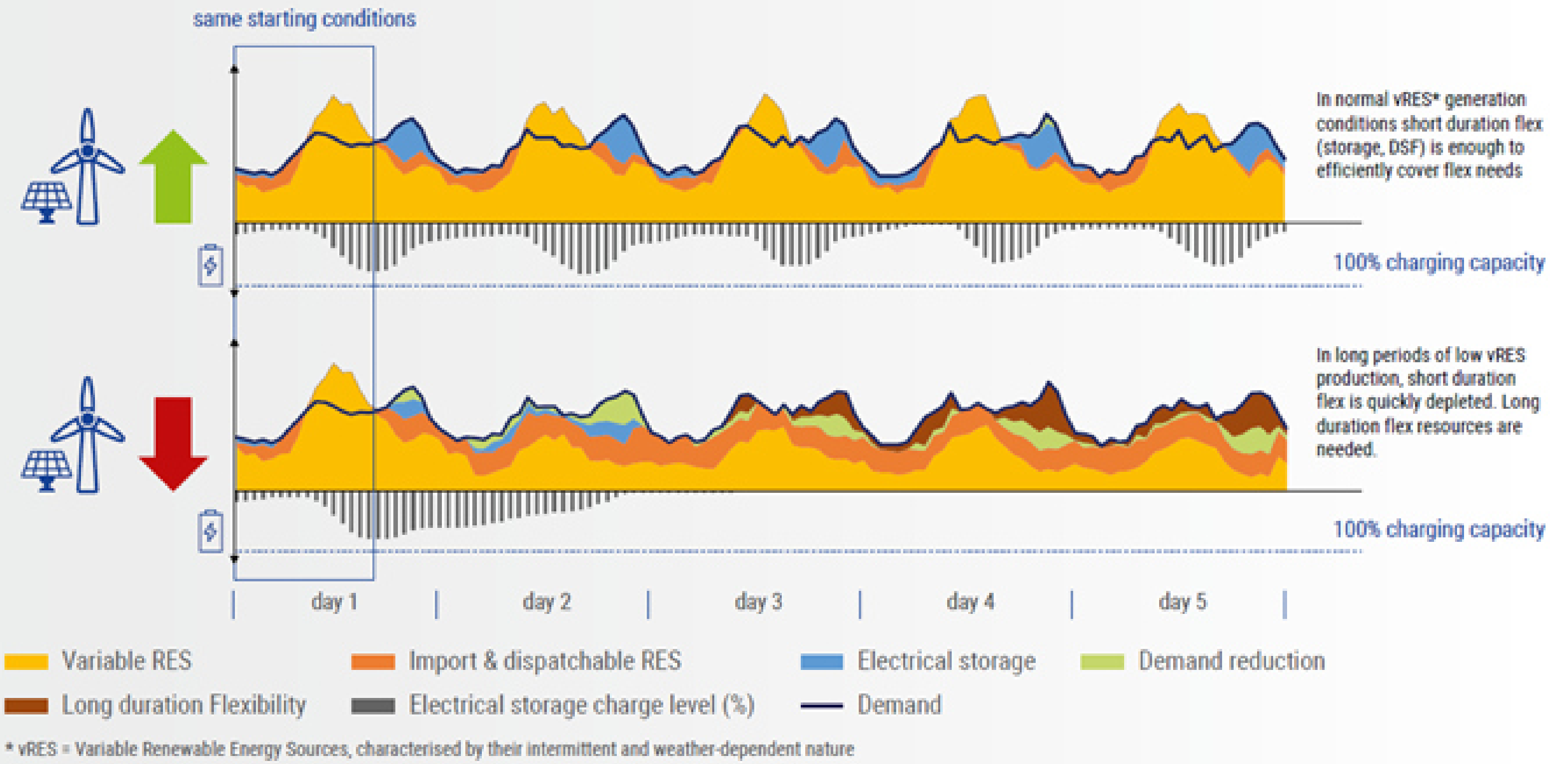


Resulting RES and demand in January

The future is already here



Short and long duration flexibility



Use of short-duration and long-duration flexibility resources in different grid conditions

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Flexibility matrix

long duration	short duration			

Source \ Need		Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation					⬇
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitors			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

⬇ Phase-out by 2050 ● Most promising ○ Contributing

Legend

⬇ Resources expected to be phased-out by 2050

● Most promising resources to cover needs / for wider diffusion vs today

○ Other resources contributing to covering needs / which diffusion is subject to technological developments or national/regional specificities

- This is a high-level, qualitative and non-exhaustive analysis of flexibility resources, to be used as **starting point for discussion**
- Since **no single recipe for all Europe is expected**, it is likely that the matrix would differ at national/regional level
- **Nuclear power** is a relevant option in some countries and changes the picture to some extent for them

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Flexibility matrix

Source \ Need		Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	↓	↓	↓	↓	↓
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

↓ Phase-out by 2050 ● Most promising ○ Contributing

- There are **very few potential resources** of carbon-neutral long duration flexibility.
- **Dispatchable RES** (**hydro, bio, geothermal**) are among the promising ones, but their further development is subject to national specificities and strategies
- The most promising solution could be **hydrogen** – produced from carbon neutral generation, stored, and subsequently used for power generation when required by the system
- Other **alternatives** could emerge assuming that further technological progress is made to decrease their cost and improve their capacity to store energy

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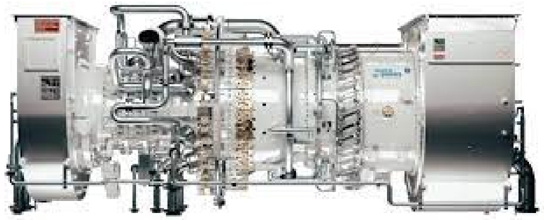
Some reflections

- Without actions, **enormous** amounts of power will be lost
- This would be a **huge** waste of resources and make renewable resource **very expensive** (because a large share of their production would be lost)
- But it will not happen, if we allow **markets** to work
- Power for free (or even cheaper) will create **strong incentives** to develop new solutions, improve existing solutions and invest
  - **Storage** will be part of any relevant solution
  - **Sector coupling** (heat, gas…)
- It is difficult to anticipate how the **hydrogen value** chain will develop
  BUT in a 100% carbonfree power system:
  - There is presently no obvious other application for large scale deployment of **excess RES generation**
  - There is no obvious alternative to cover a "**dunkelflaute**"
- These are **very strong drivers** to develop hydrogen solutions for these purposes

Dutch government will support conversion of gas turbines to H2



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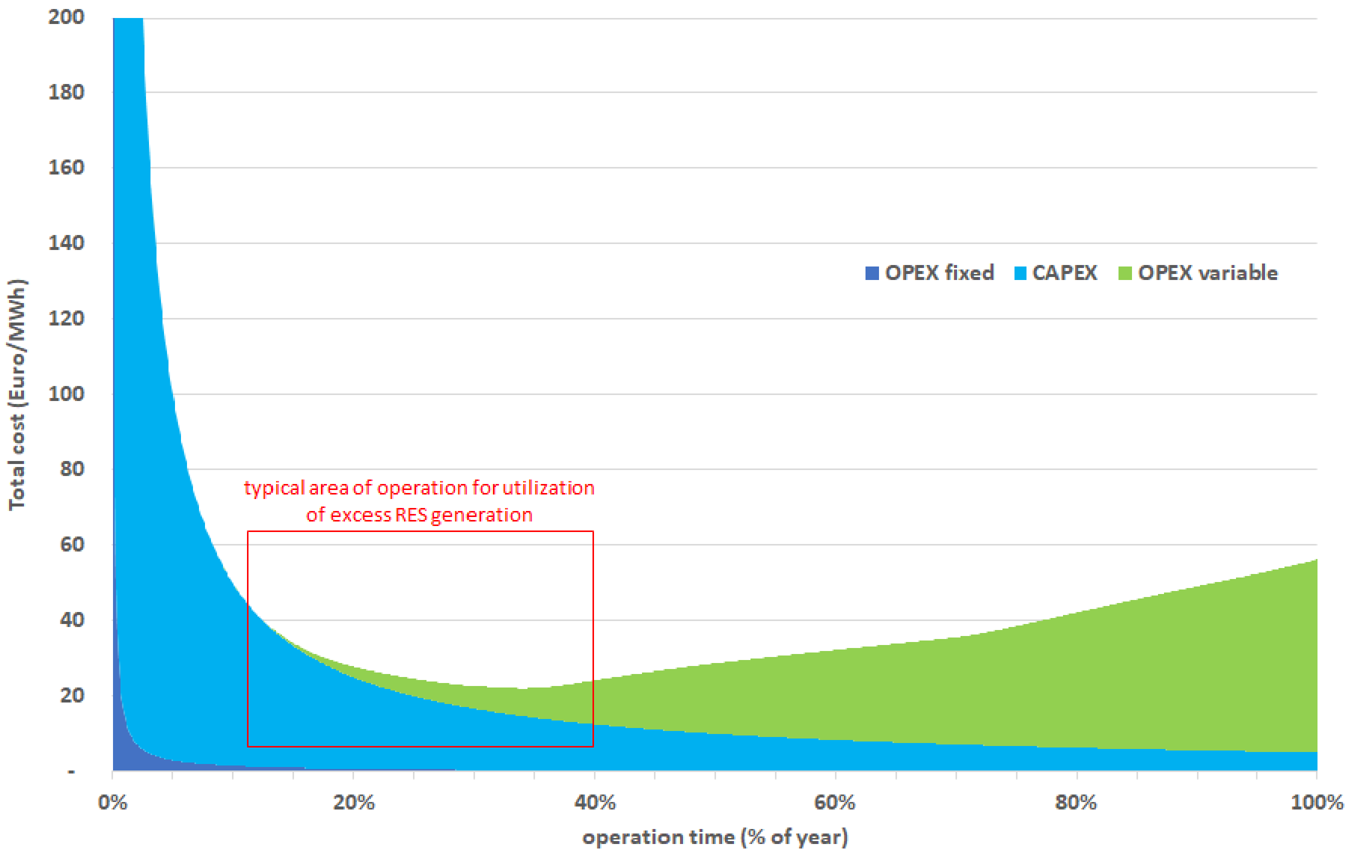
Cost of hydrogen electrolysis



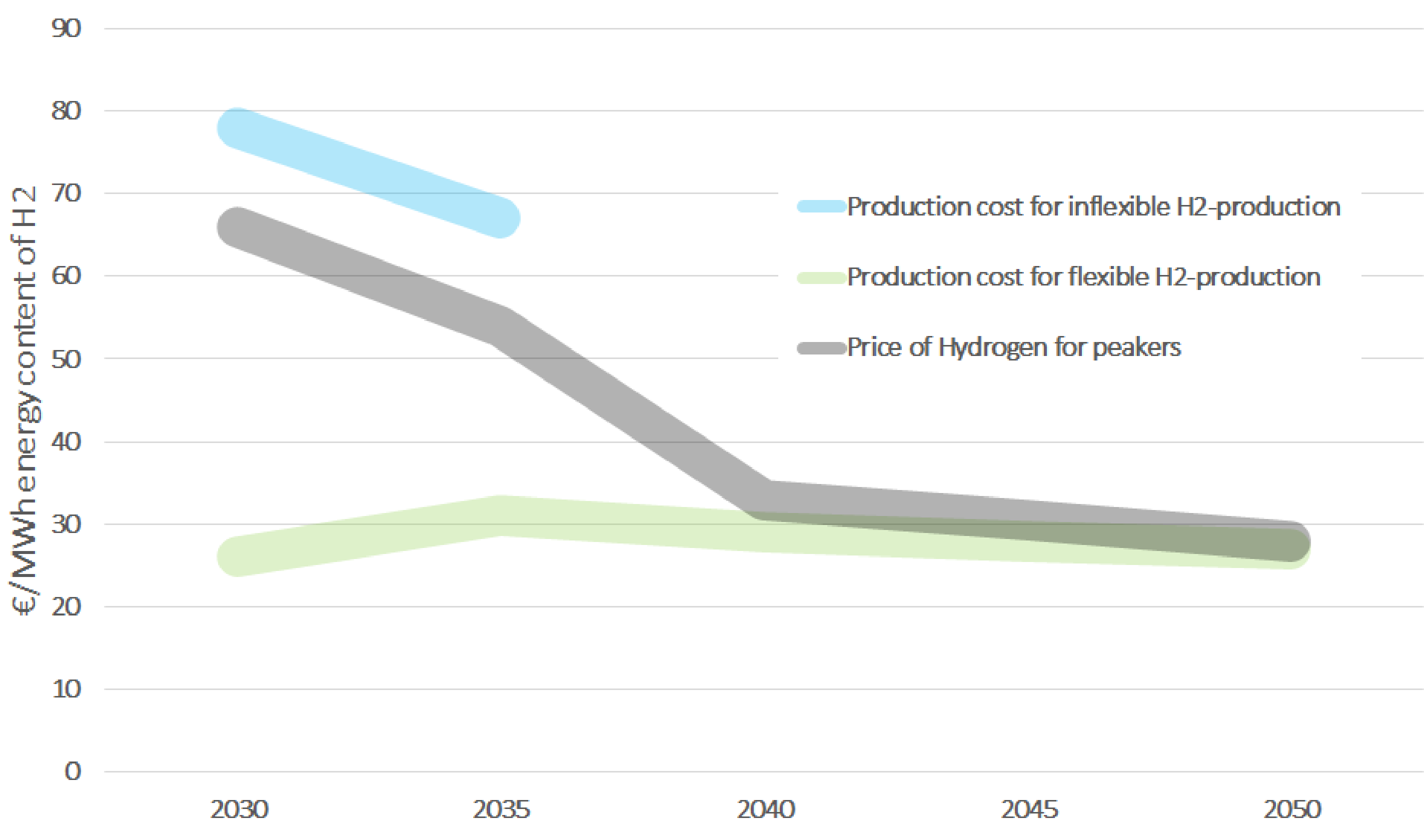
- Cost estimates are quite uncertain
- With our assumptions they will be between 20 and 40 Euro/MWh for hydrogen around 2030
- Assuming 30% efficiency of H2 GT and electricity cost of 10 Euro/MWh, total cost will lie around 50 Euro/MWh
- Even twice this cost would be a very acceptable price for 1000 hours/year!

Based on simulated prices for Germany, 2030

Source: Statnett Long Term Market Analysis (in Norwegian)

https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/planer-og-analyser/lma/langsiktig-markedsanalyse-2022-2050.pdf

Operational pattern of H2-production is decisive



- Flexible H2-production will profit from (very) low power prices
- Even with higher capital cost per produced unit, this can still be a profitable strategy
- Inflexible H2-production will face (much) higher power prices
- Future duration of excess RES generation may match need for hydrogen production for a "dunkelflaute"
- The price picture should also be noted by other industries

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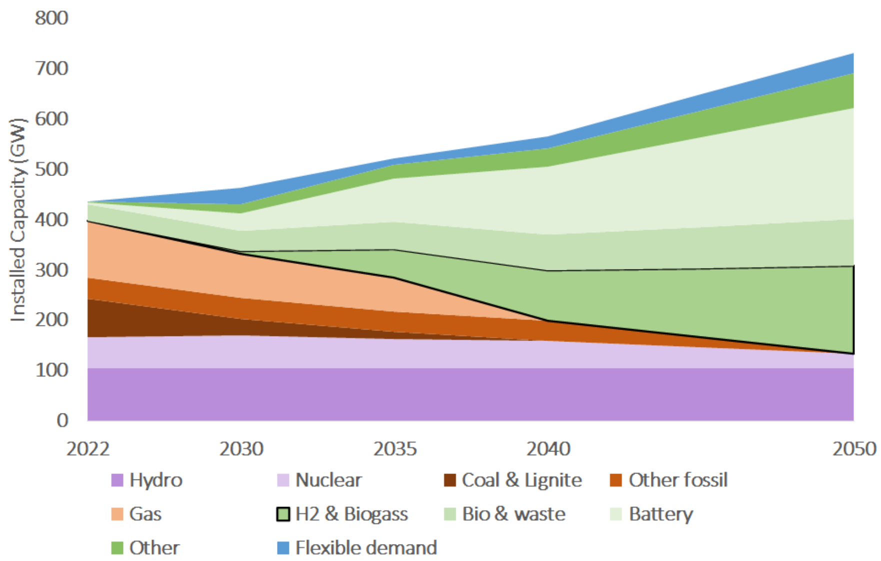
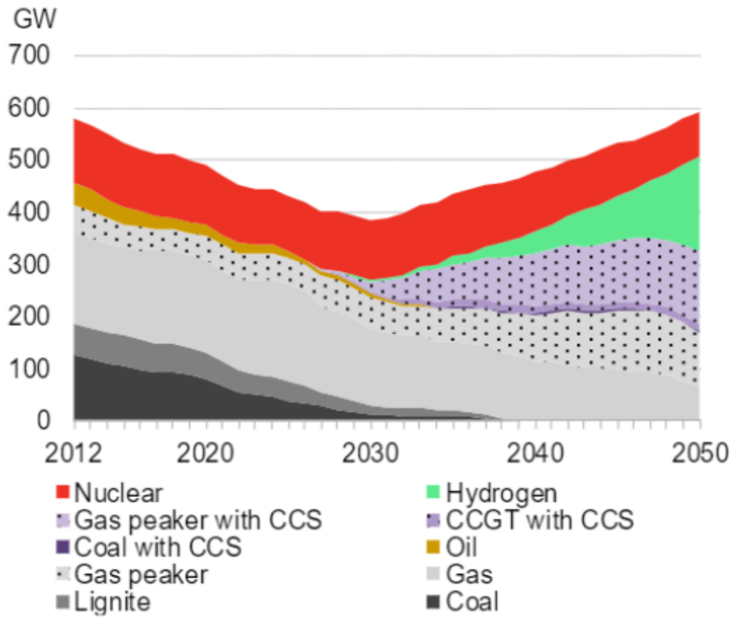
Hydrogen impact expected to accelerate from 2030





Statnett Long-term Market Analaysis 2022

- H2-impact expected to **start slowly but then accelerate fast after 2030** due to system needs, technology and cost development

Bloomberg New Energy Outlook Europe, May 2023

- Expected **very similar role for H2**, but much higher share of remaining fossil fuel, with and without CCS

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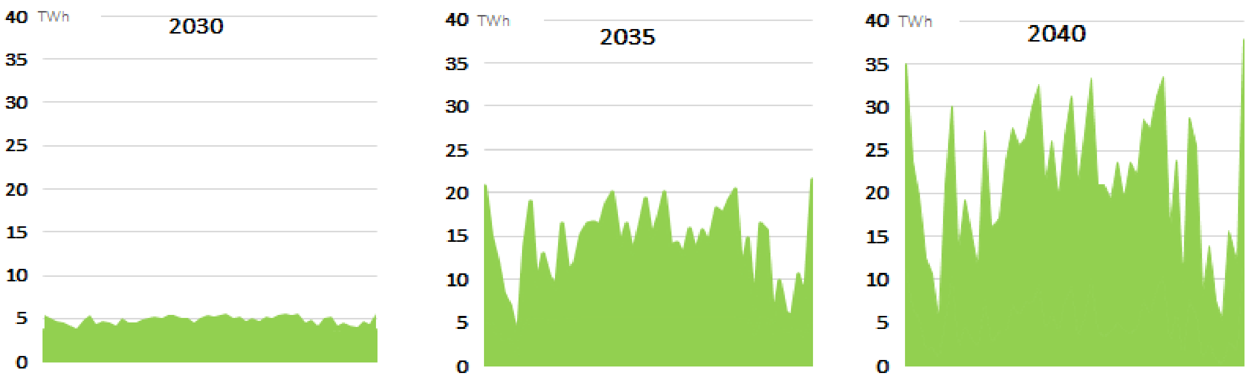
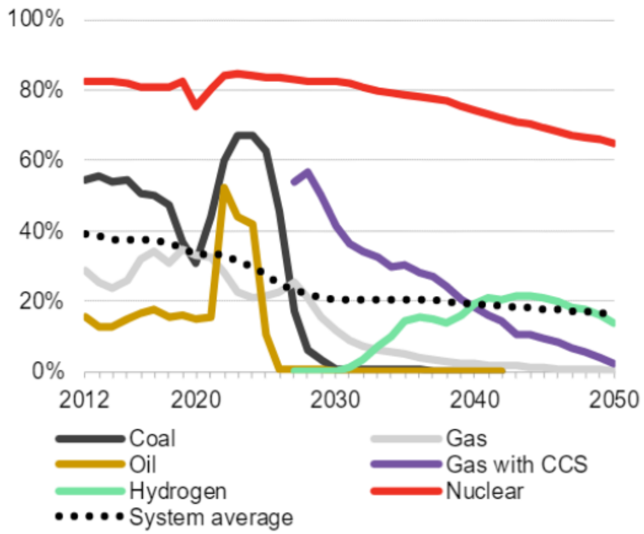
Power demand for H2-production and power generation from H2 will become more flexible and face reduced load factors



Power demand for hydrogen production

Source: Statnett Longterm Market Analysis 2022



Load factors for firm capacity in Europe

Source: Bloomberg New Energy Outlook Europe, May 2023

Conclusions

- Long duration flexibility is crucial for a future carbon free power system
- There will be contribution from several sources, but expected that green hydrogen will play a crucial role
- Excess generation from wind and solar production will be a much bigger problem than deficits *in terms of volume*
  - Not tackling this is huge waste, increases the cost of the green transition and is a lost opportunity
- A significant share of the production of green hydrogen MUST be flexible and adapt to price variations
  - Hydrogen production should not be subsidized to produce during high power prices
- Given time, companies will learn, adapt and develop new business models based on highly volatile power prices (and participation in TSO markets)
- However, as we are in a hurry for the green transition, government encouragement will be necessary to speed up the adaption of such business models