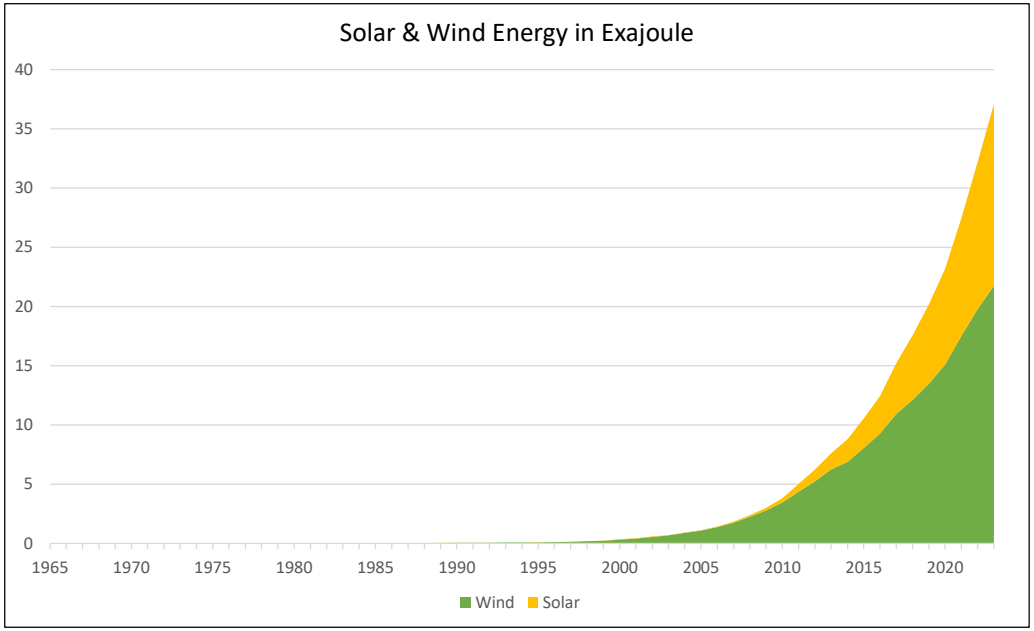
Energy Transition:

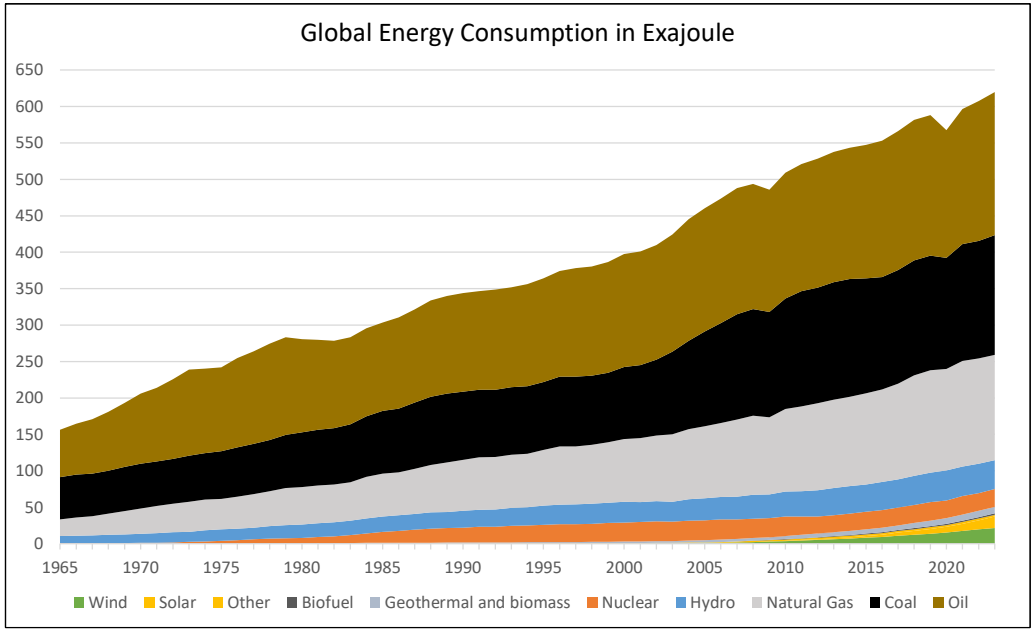
Perspectives on energy demand, European energy systems and Norway's role as a reliable oil and gas exporter

Aker BP – June 2025

Solar and wind energy looks to increase at incredible pace

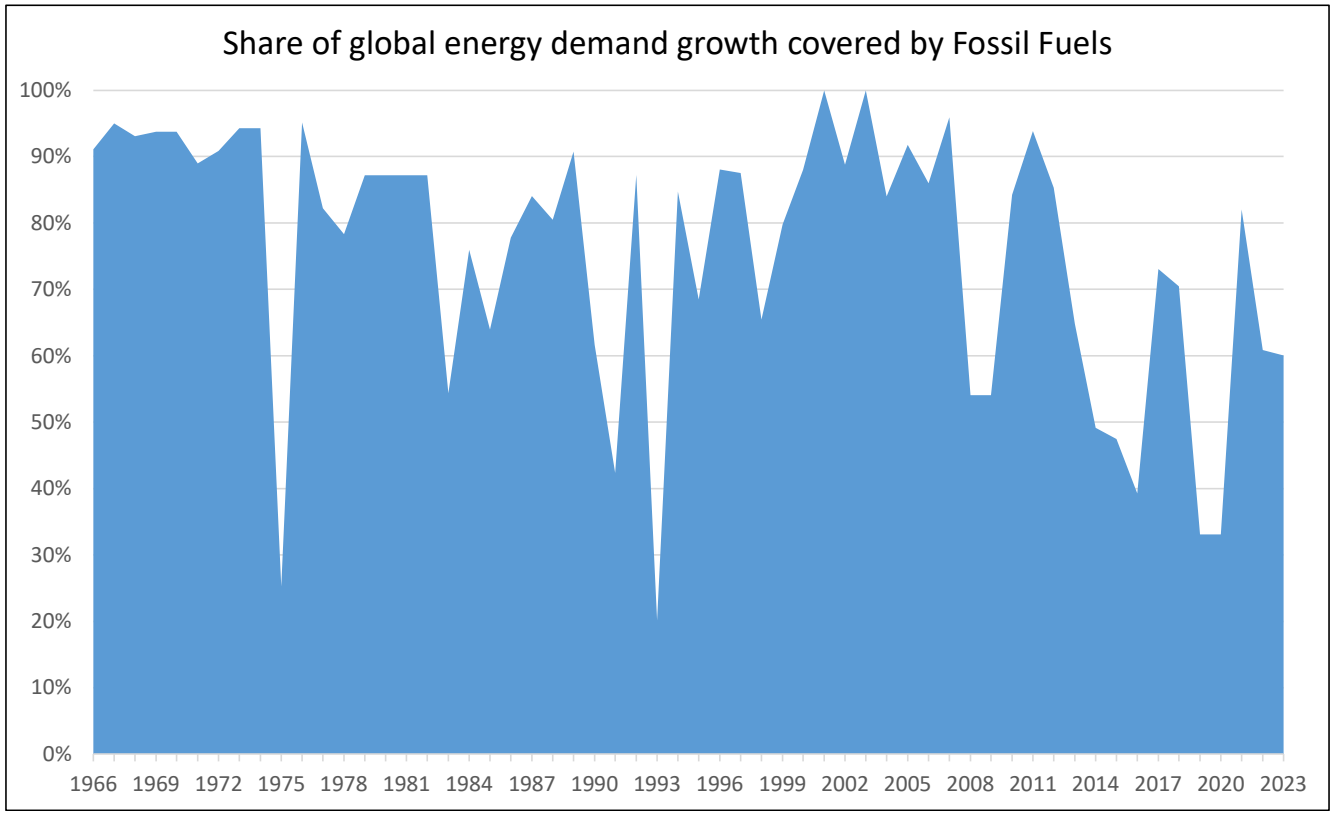
- But so far it is no Energy Transition taking place, only Energy Addition





After COVID 60-80% of energy demand growth covered by fossil fuels

- The first step is to cover energy demand growth from renewables, maybe we can get there some day

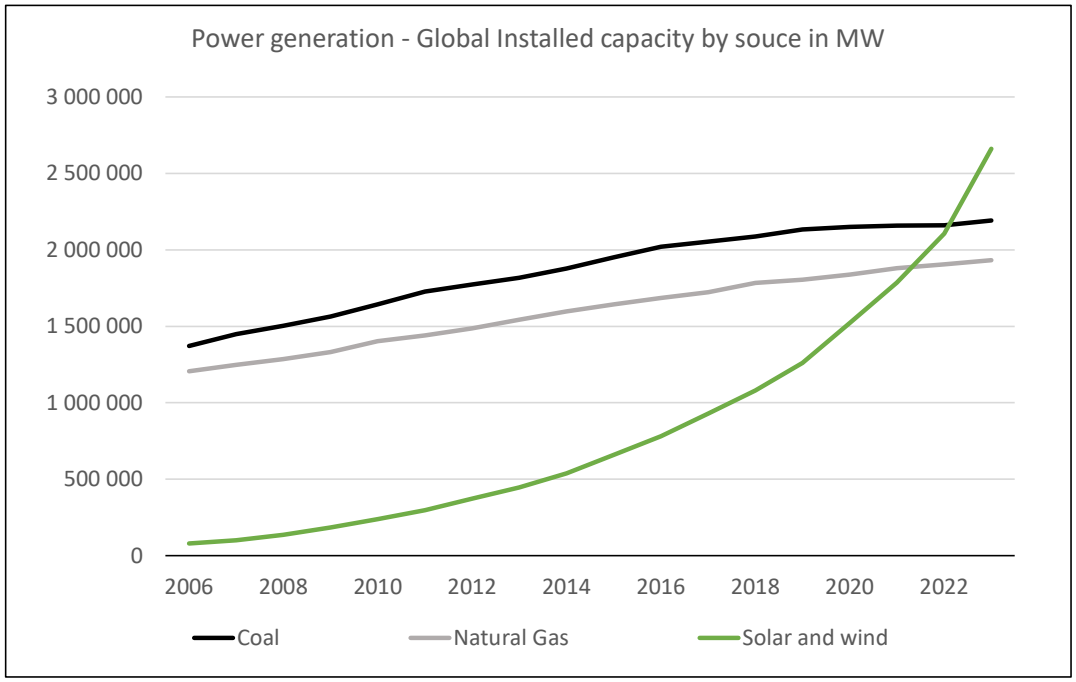


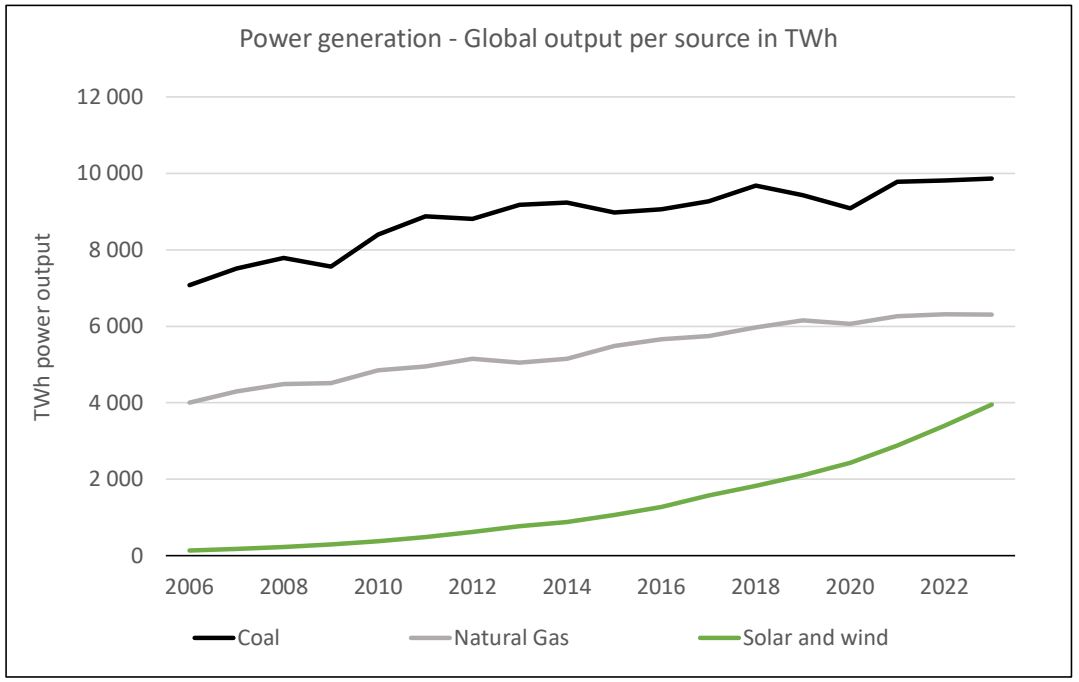
Wind power - Offshore and Onshore	
Installed wind capacity in 2023 in GW	1 015
Theoretical wind production in 2023 in TWh	7 977
Wind power production 2023 in TWh	2 336
Utilization of installed wind	29,3 %
Installed number of GW 2023-2030 to match half final energy demand consumption growth	2 458
Annual wind installation required in GW	351
Installed wind in 2024 in GW	133
IEA accellerated case for wind 2024-2030	1 279
Lack of wind installation in acellerated IEA case to cover half final energy consumption - GW	**1 046**

Solar power - PV off grid, PV residential system, PV commercial system	
Installed solar capacity in 2023 in GW	1 612
Theoretical solar production in 2023 in TWh	12 666
Solar power production 2023 in TWh	2 136
Utilization of installed solar	16,9 %
Installed number of GW 2023-2030 to match half final energy demand consumption growth	4 267
Annual solar installation required in GW	610
Installed solar in 2024 in GW	552
IEA accellerated case for solar 2024-2030	2 015
Lack of solar installation in acellerated IEA case to cover half final energy consumption - GW	**1 700**

Enormous increase in *installed capacity* for solar & wind

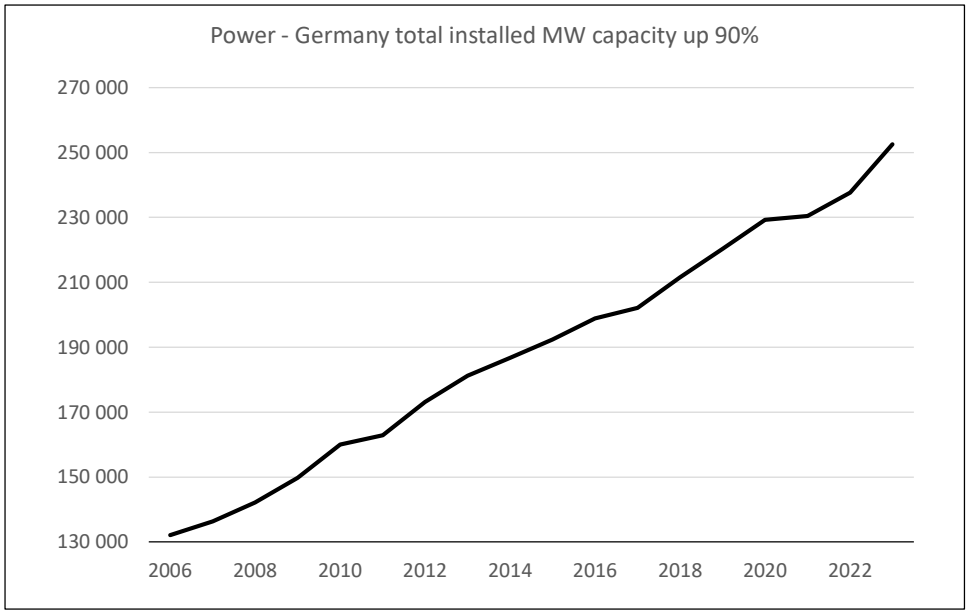
- When looking at *installed capacity* – solar & wind has already surpassed coal & natural gas
- But when looking at the *output of power in TWh ,* solar & wind is only one quarter of coal & natural gas



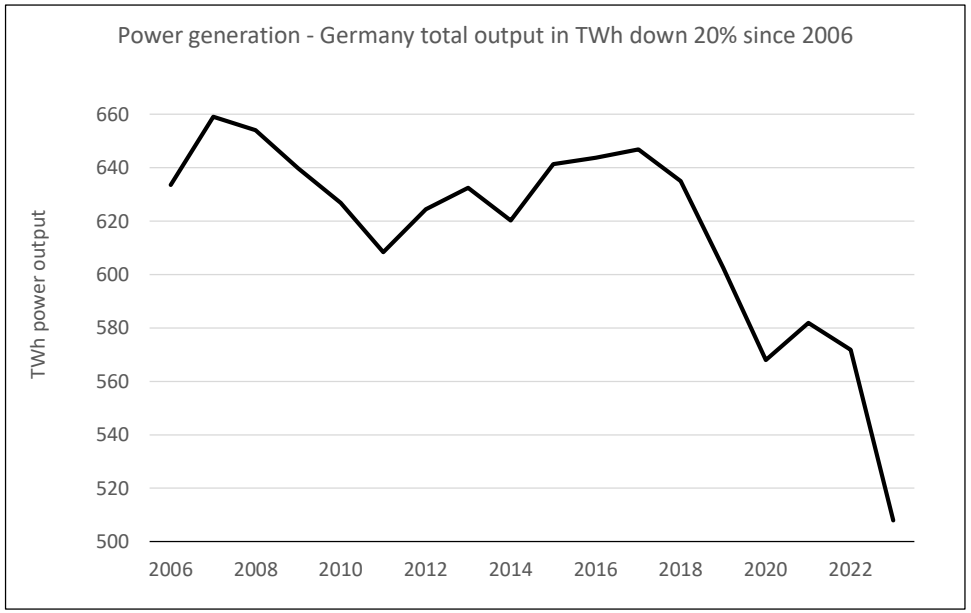


Total installed MW capacity in Germany increased massively

Total installed power production capacity in Germany is up 90% since 2006



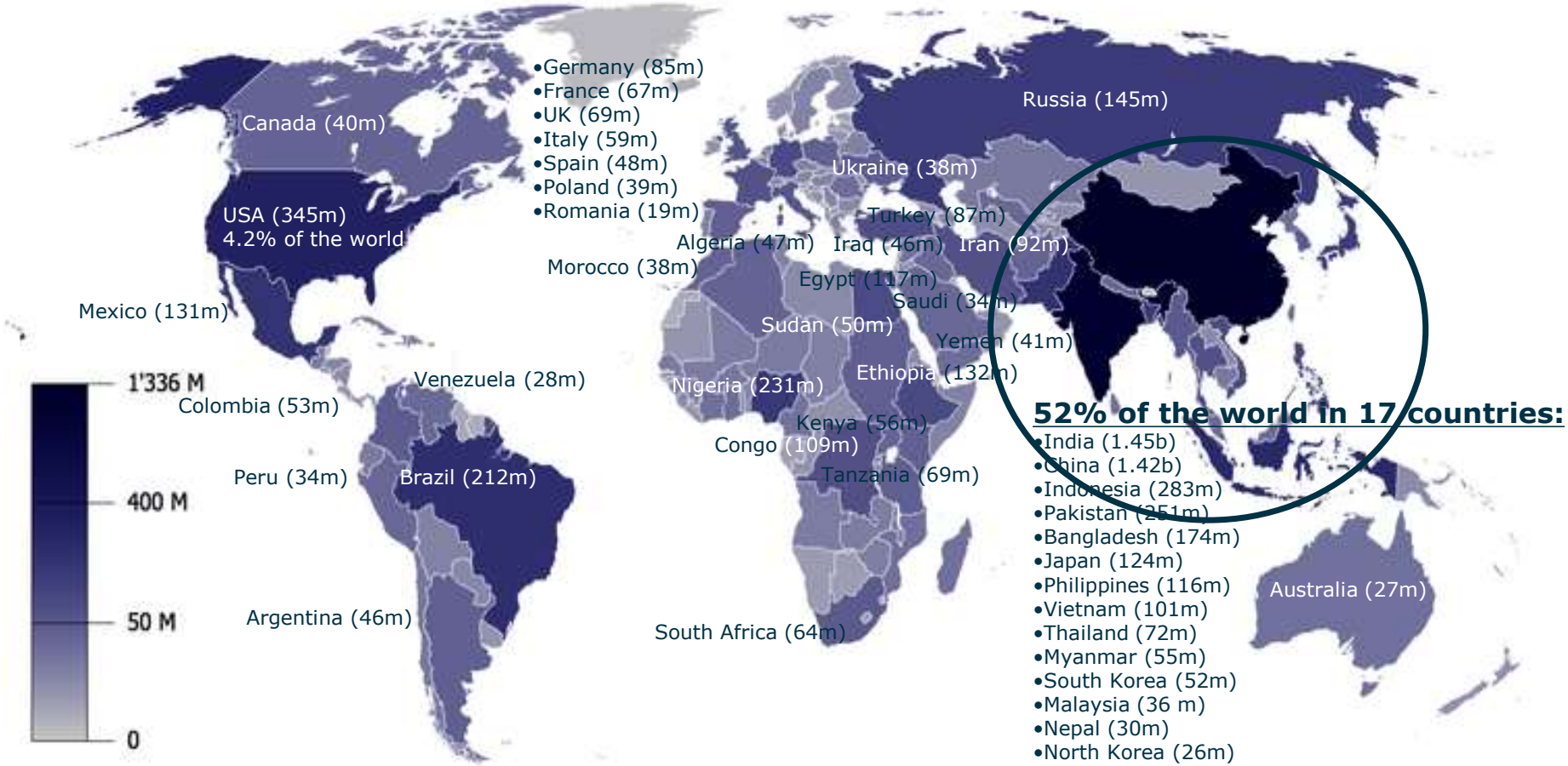
Despite this effort of "Energiwende", power output in TWh is down 20% in the same period



Source: BloombergNEF

World population by the largest countries

- Source: United Nations Population Division



52% of the world in 17 countries:

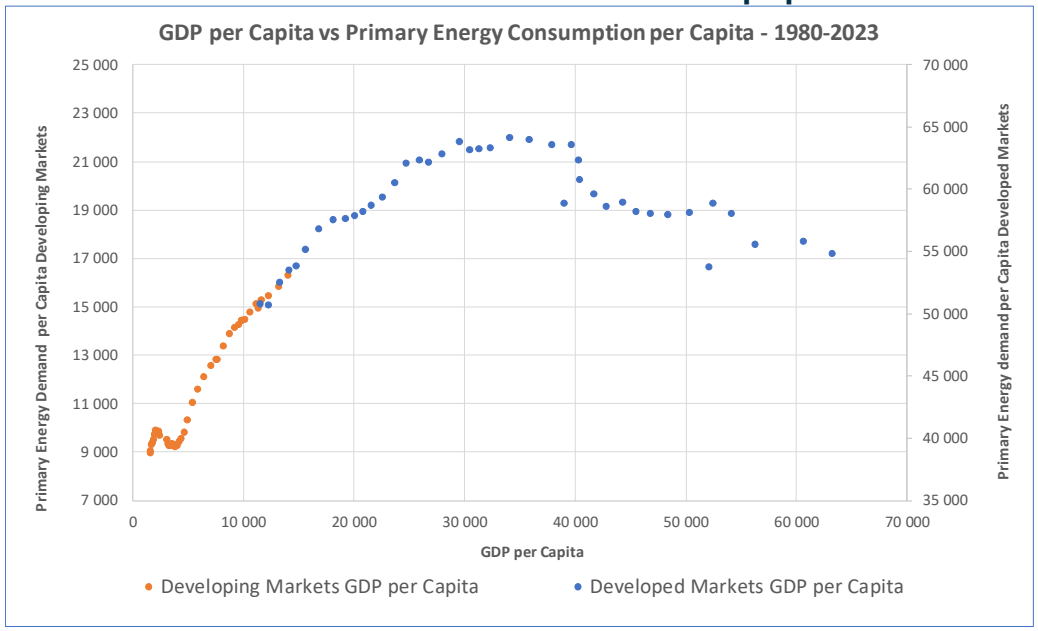
- India (1.45b)
- China (1.42b)
- Indonesia (283m)
- Pakistan (251m)
- Bangladesh (174m)
- Japan (124m)
- Philippines (116m)
- Vietnam (101m)
- Thailand (72m)
- Myanmar (55m)
- South Korea (52m)
- Malaysia (36 m)
- Nepal (30m)
- North Korea (26m)
- Taiwan (23m)
- Sri Lanka (23m)
- Cambodia (18m)

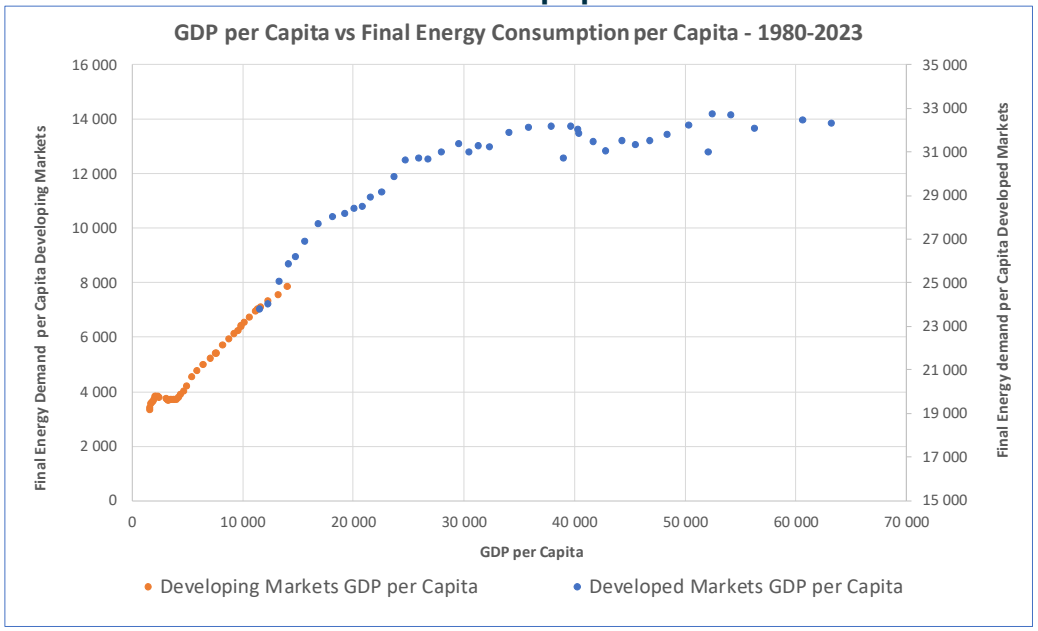
GDP per capita growth in EM suggest energy demand growth for decades

- 80% of the world lives in EM (red dots) which suggest we should have decades ahead of energy demand
- Final energy demand (usable energy) per capita does not fall, only flatlines even in OECD
- IEA's Announced Pledges Case assumes that this relationship reverses

Why is it so difficult to turn this trend in the Emerging Markets?

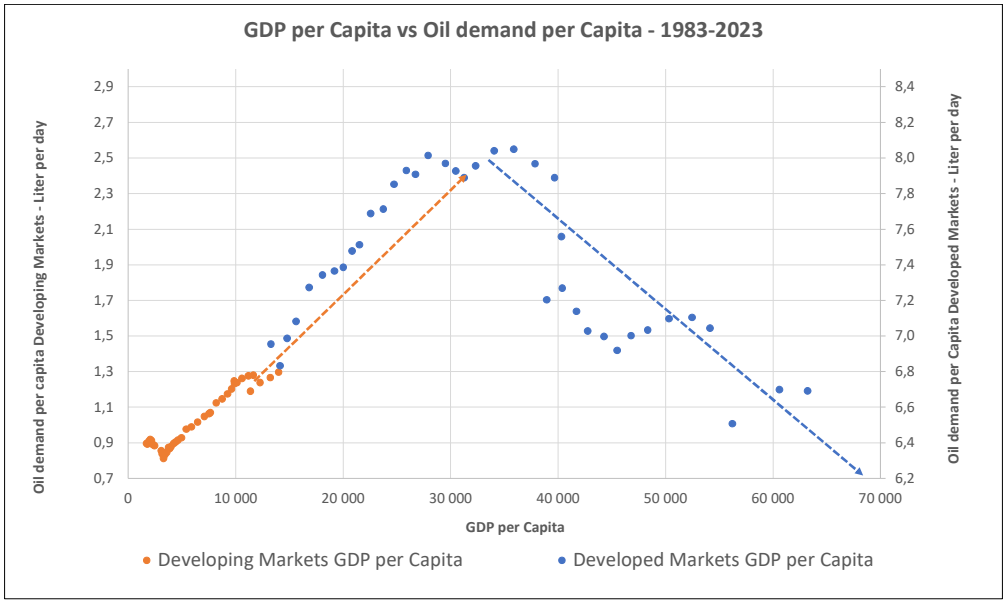
- 85% of all people alive today has never been on a plane
- 4 billion people inhabit less than 10 square meters of living space, less than a western prison cell
- A hot tub in the Alps can consume more electricity than an African village of 40 people
- The US is 4% of the world population but consumes 20% of the worlds toilet paper

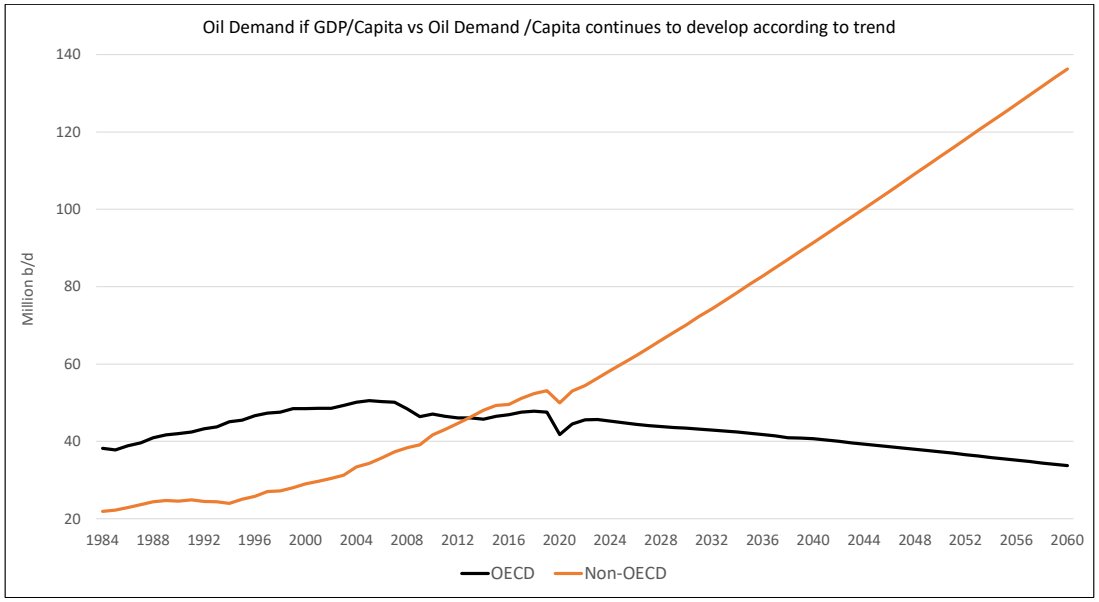




If Non-OECD trend continues oil demand has decades left to grow

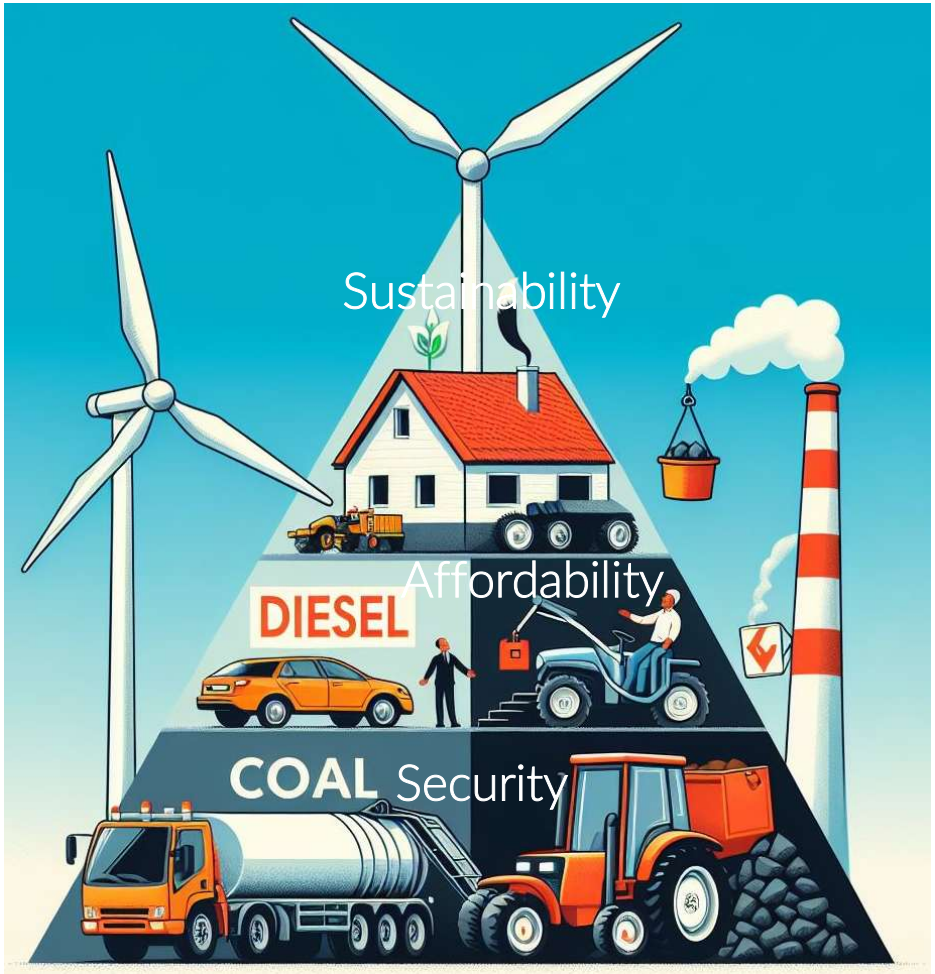
- If oil demand/capita reach 2.3 liters/day in Non-OECD, then oil demand will reach almost 140 million b/d





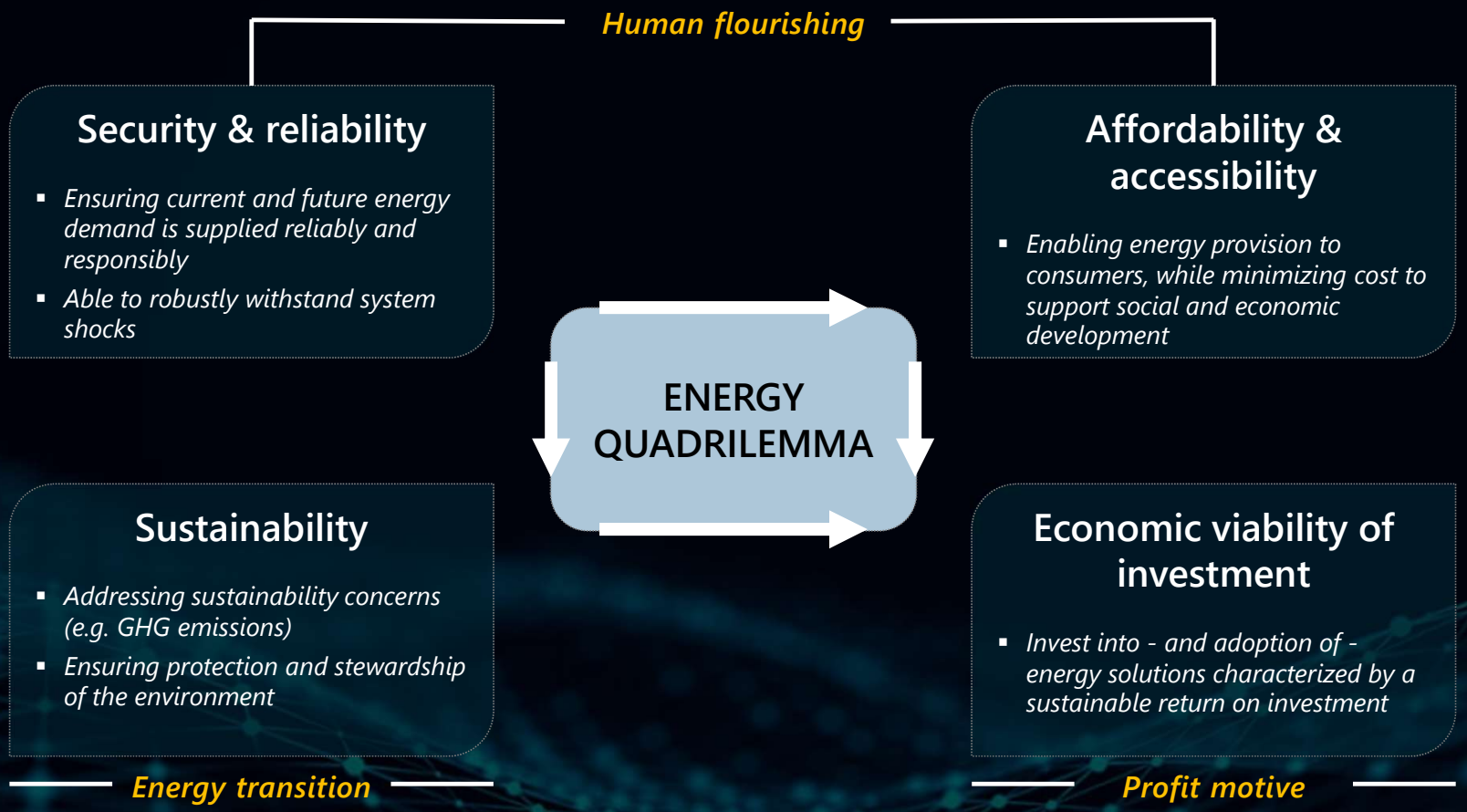
The Energy Trilemma – In reality it is a Maslows' hierarchy of needs

- Governments will always prioritize security before sustainability (because of their electorates)



The Energy Quadrilemma – Achievable to reach all goals?

In reality, governments will always prioritize security before sustainability



Source: Lambert Energy

Companies inside the Global Clean Energy Index keeps on trending down

- Economic viability, part of the energy quadrilemma still not there – It needs to be for a successful transition

Orsted shares tumble after company ditches two US wind projects

Danish developer's deepening difficulties come as top BP executive says US market is 'broken'

Det svenske batterieventyret er blitt et milliardmareritt. Hva skjedde?

De lovet å revolusjonere det grønne skiftet i Europa. I stedet sliter gigantfabrikken med gjeld, milliardtap, mystiske dødsfall og ordrer som forsvinner.

Den pressede batterigiganten Northvolt sliter med gjeld og produksjonsproblemer. Deler av fabrikken i Skellefteå, der dette bildet ble tatt for ett år siden, må stenge. *Foto: Arkivfoto: Linus Sundahl-Djerf, Svenska Dagbladet*

Solcelleselskapet Otovo skal kutte 166 stillinger

Solcelleselskapet skal kutte kostnader med inntil 225 millioner kroner årlig. For å ta ned utgiftene kutter selskapet 166 stillinger de kommende ukene.

Batteriselskap med dundrende tap

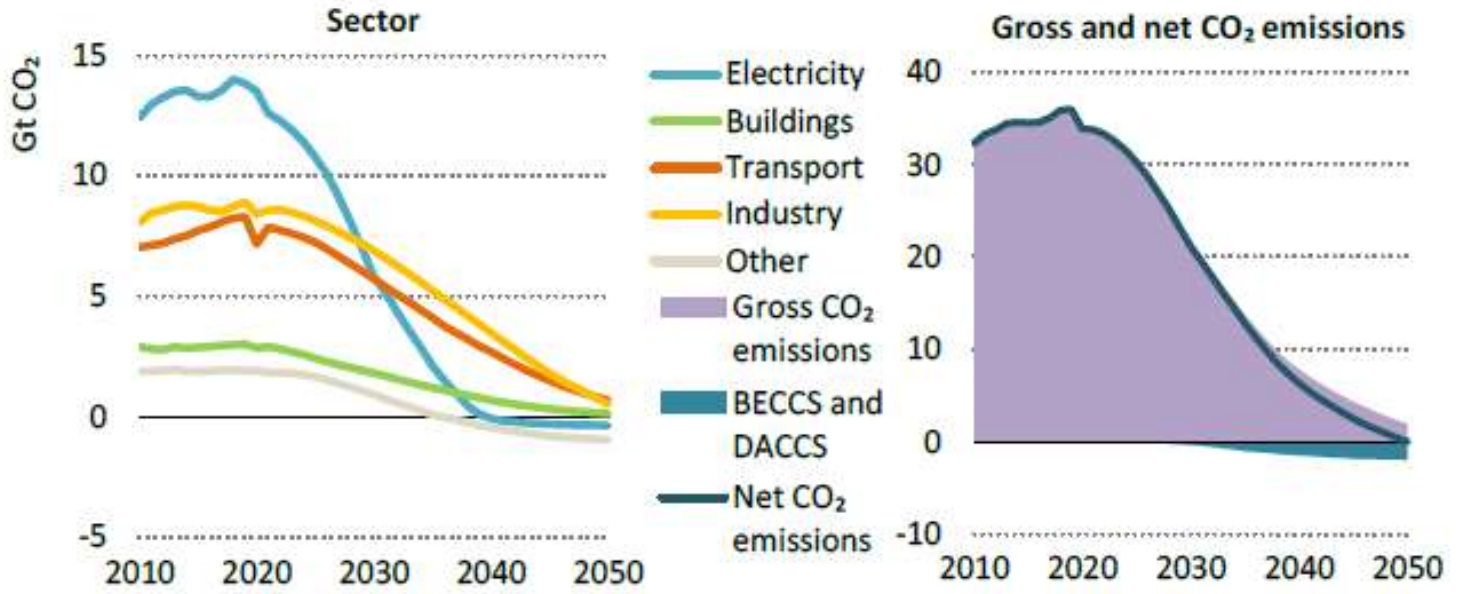
Freyr tapte 295 millioner kroner etter skatt i andre kvartal, ifølge nye tall.

Ørsted Pulls Plug on Shipping E-Methanol Fuel Project Citing Slower Demand

The first effort to reach climate targets is to green the power sector

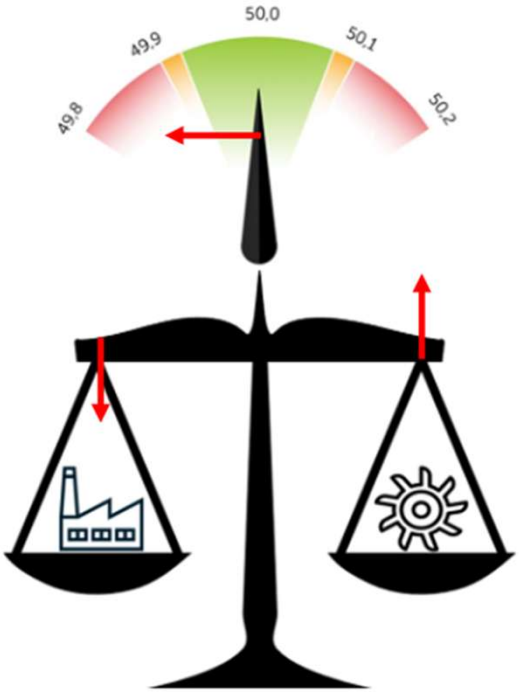
- And when the electricity sector hits zero then the rest of the sectors can turn electric

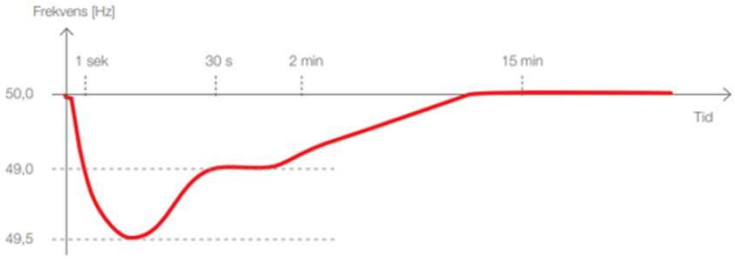
Figure 2.3 ▷ Global net-CO_2 emissions by sector, and gross and net CO_2 emissions in the NZE



Emissions from electricity fall fastest, with declines in industry and transport accelerating in the 2030s. Around 1.9 Gt CO_2 are removed in 2050 via BECCS and DACCS.

The power market needs to balance supply vs demand at all times



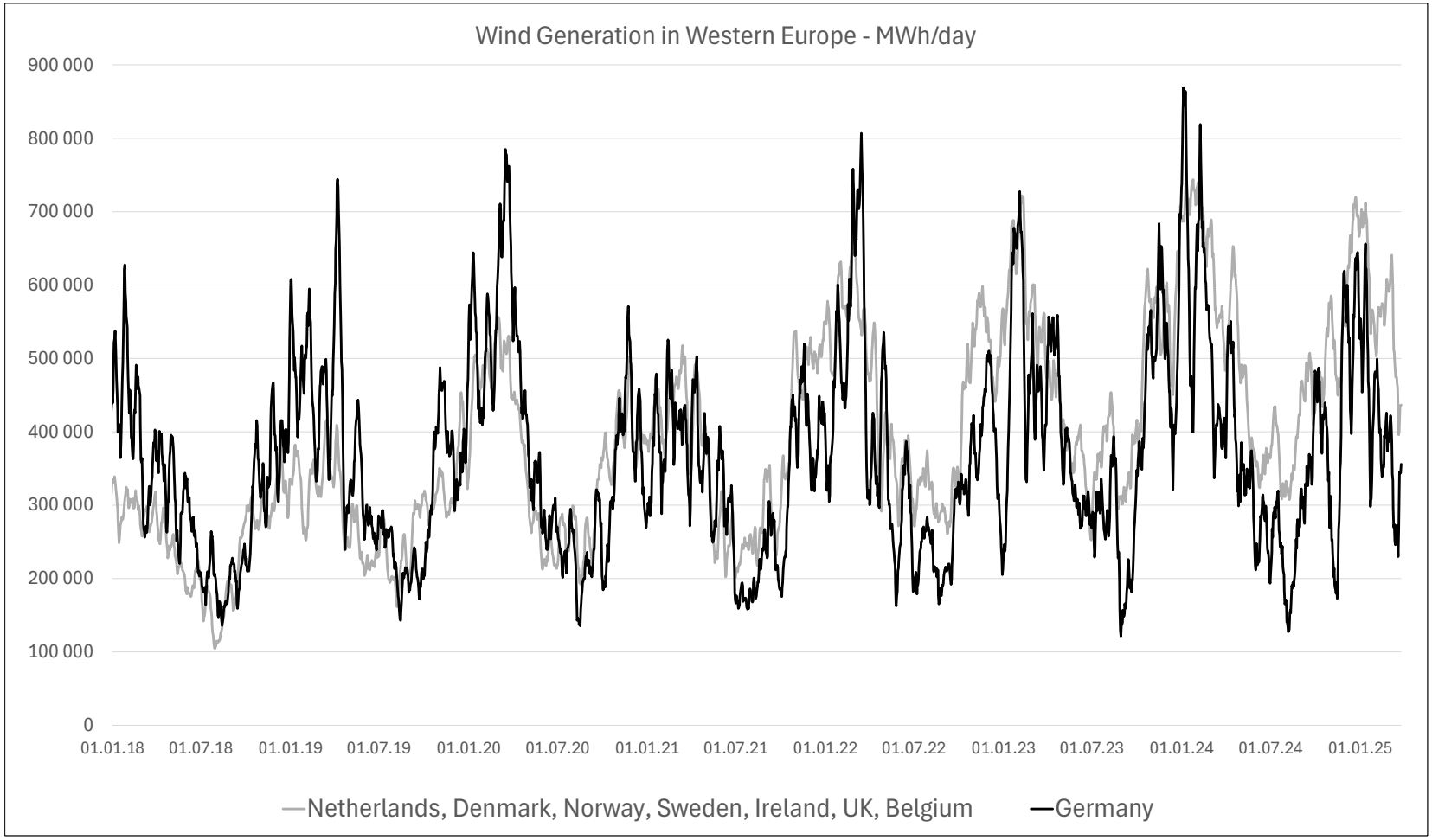


Unlike the fossil fuel market - the power market needs to balance consumption vs production at all times - 24/7 - in order to secure that the grid is not collapsing

Source: Aker Solutions

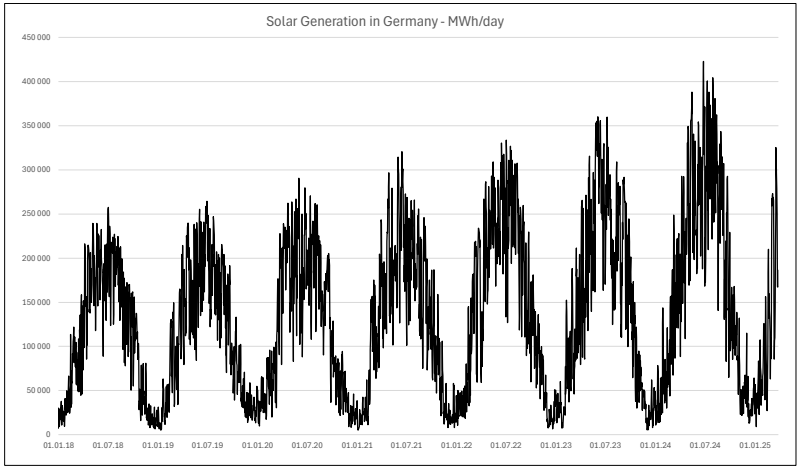
The first challenge is that the wind blows at the same time in Western Europe

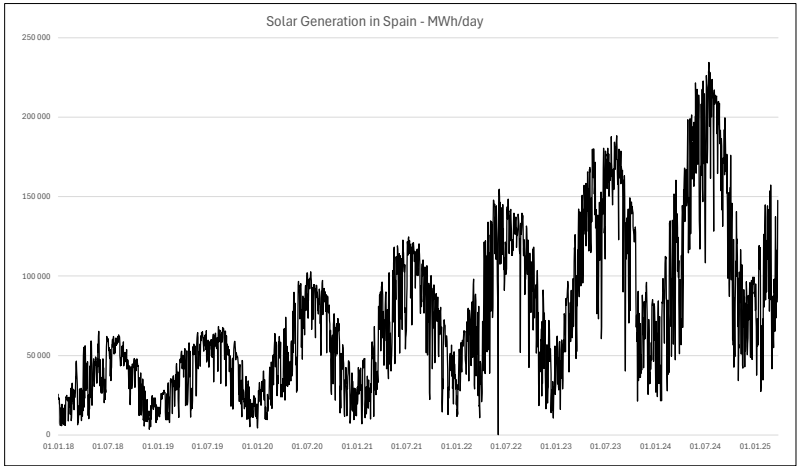
- Germany produces most of Western Europe's wind energy, but the rest of the countries have wind at the same time

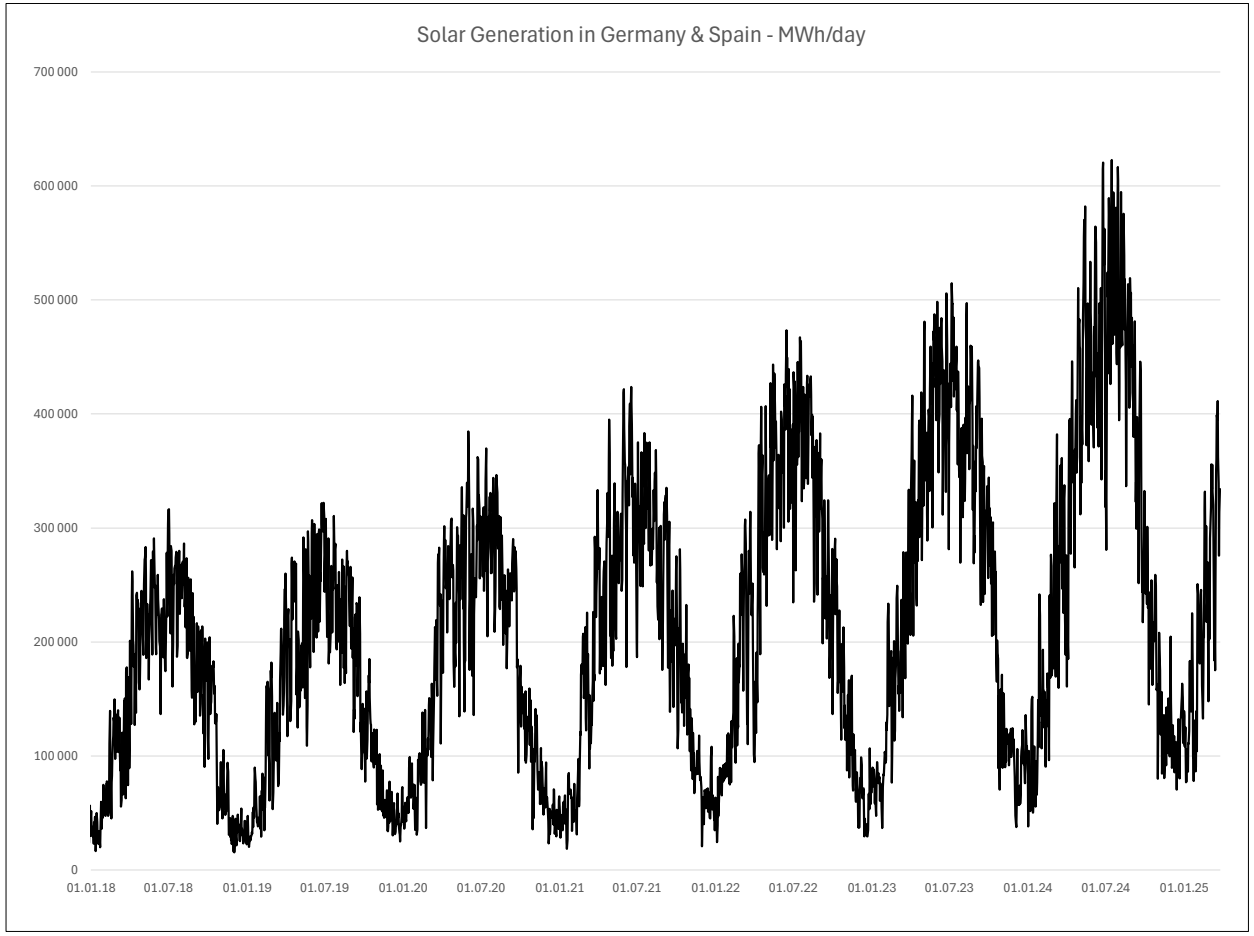


Solar power is extremely seasonal – drops >80% from summer to winter

- Despite much more installed capacity, winter levels in Germany are close to zero power output from solar…

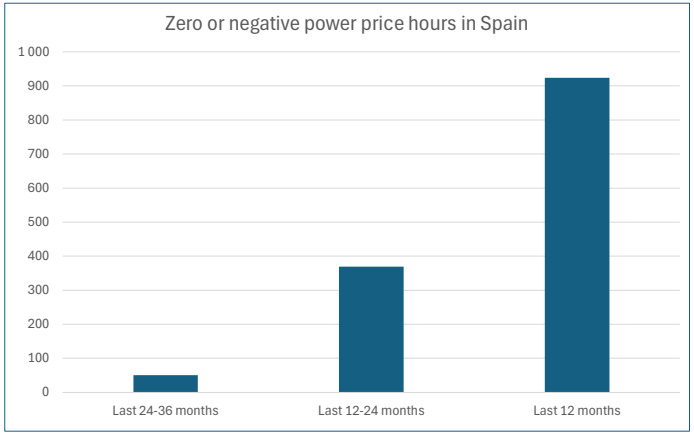


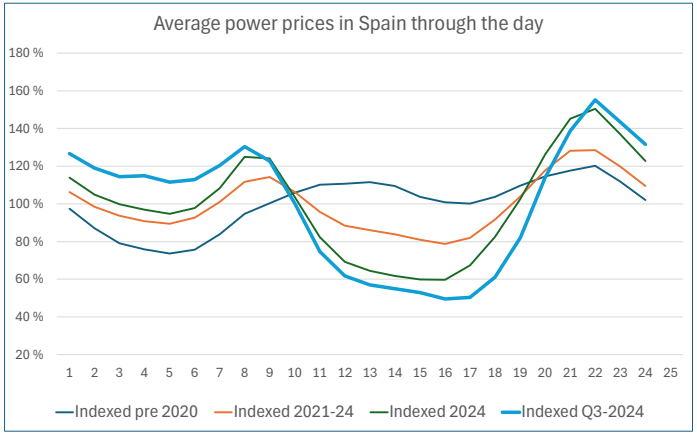


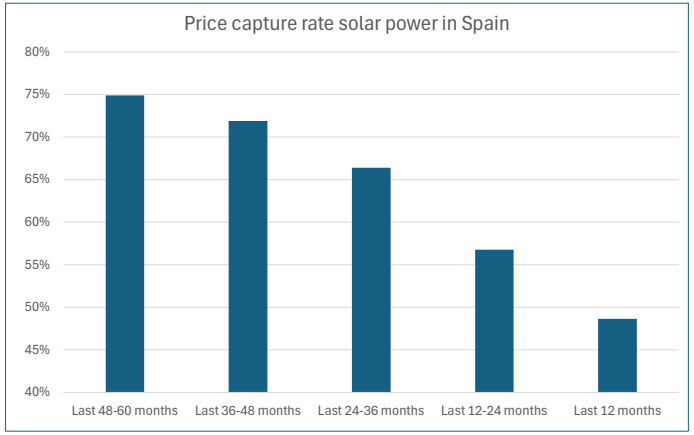


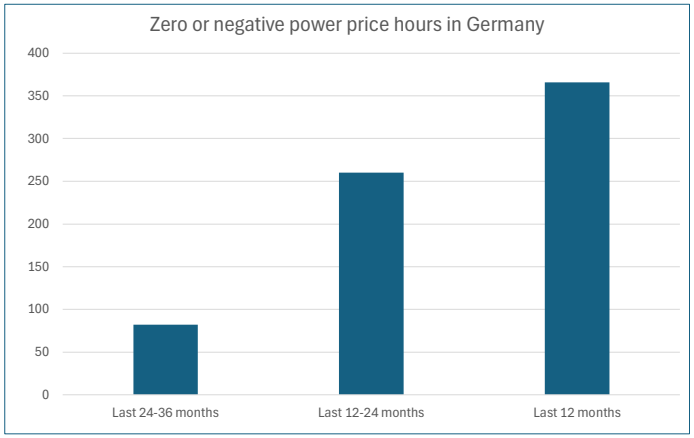
We are already at solar installed capacity that leads to negative prices

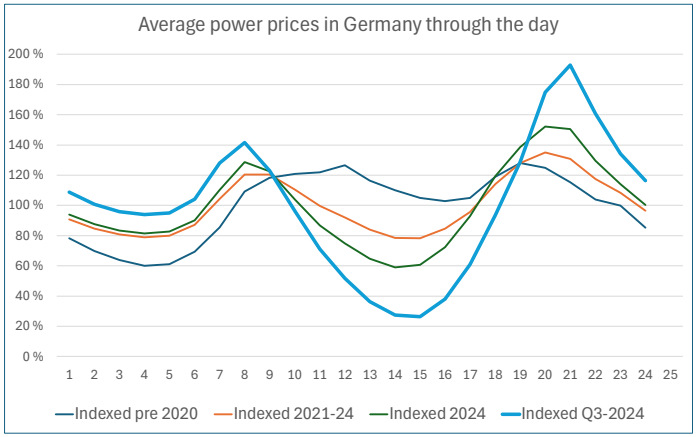
- Negative price hours is rising quickly, so achieved prices for solar produced power are collapsing
- It begs the question if the build out pace will slow going forward – BNEF believes so

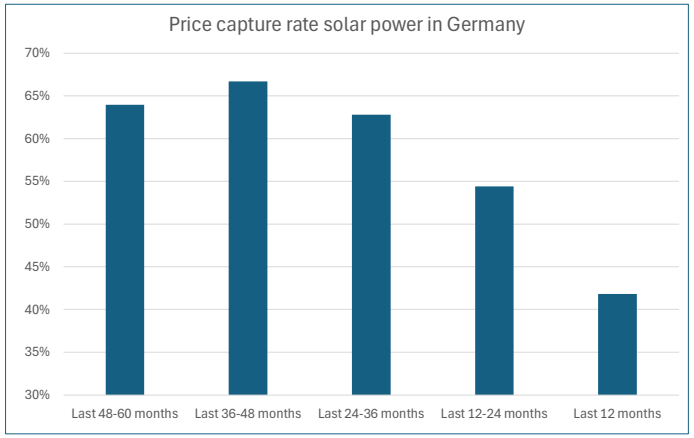






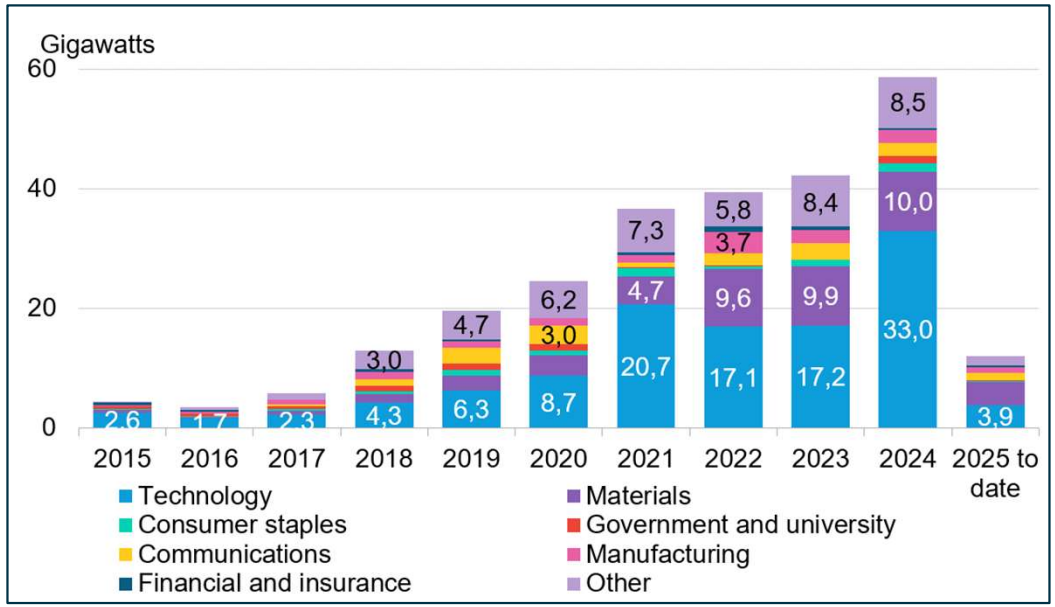


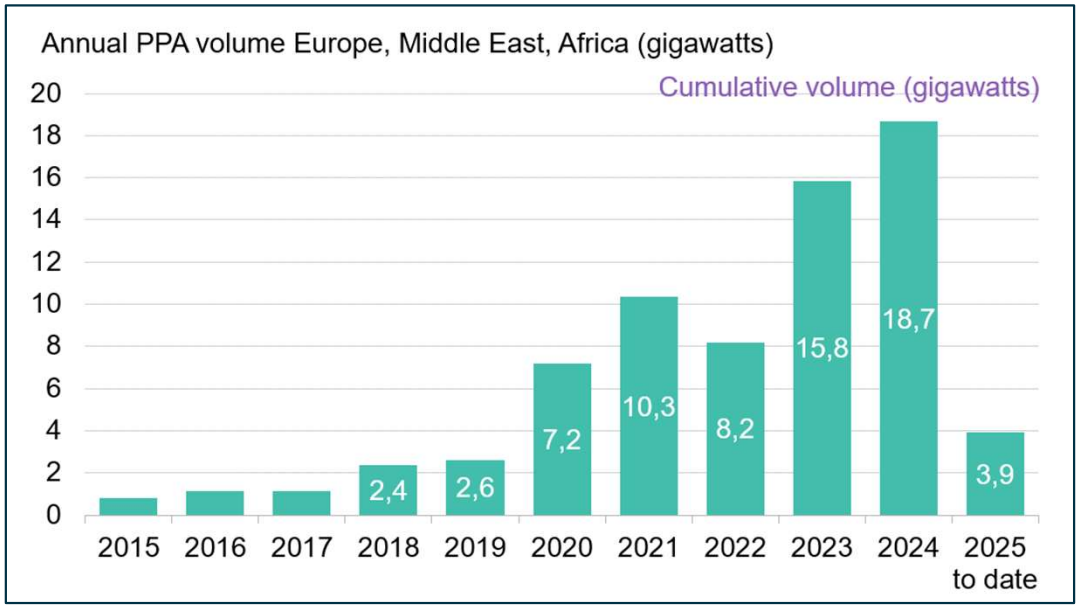


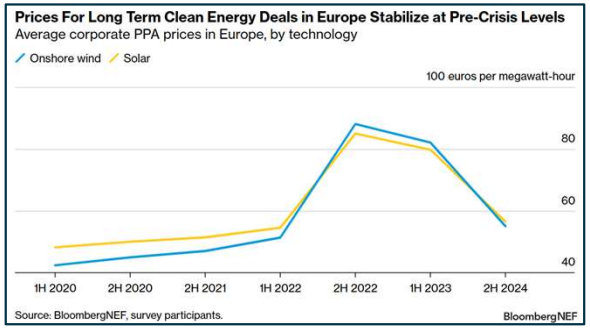


PPA's have been dominated by Microsoft, Google, Amazon, etc

- But those companies also know how to use a calculator…

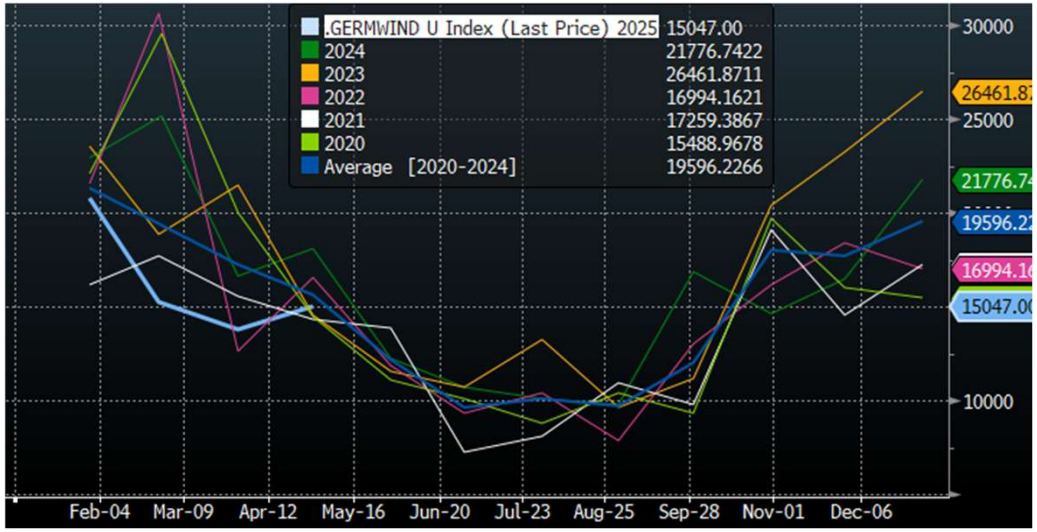


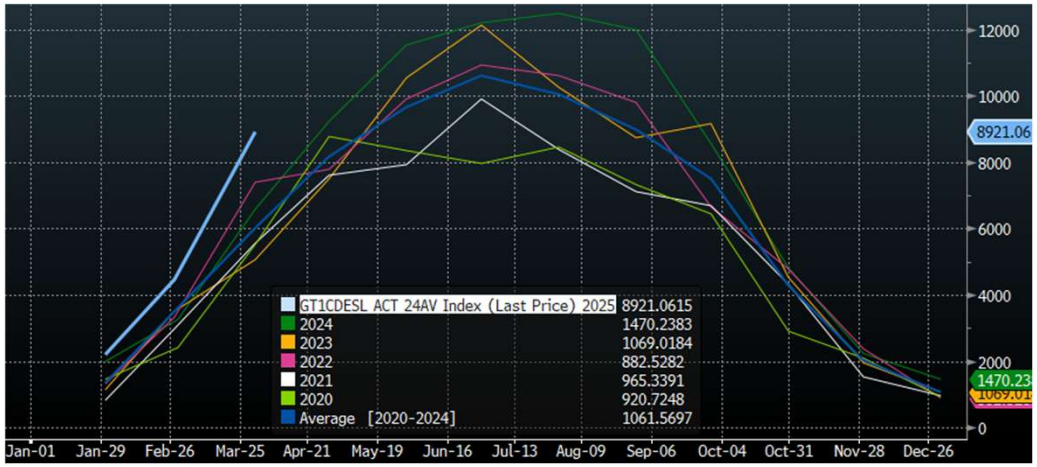




Solar power and wind power has opposite seasons

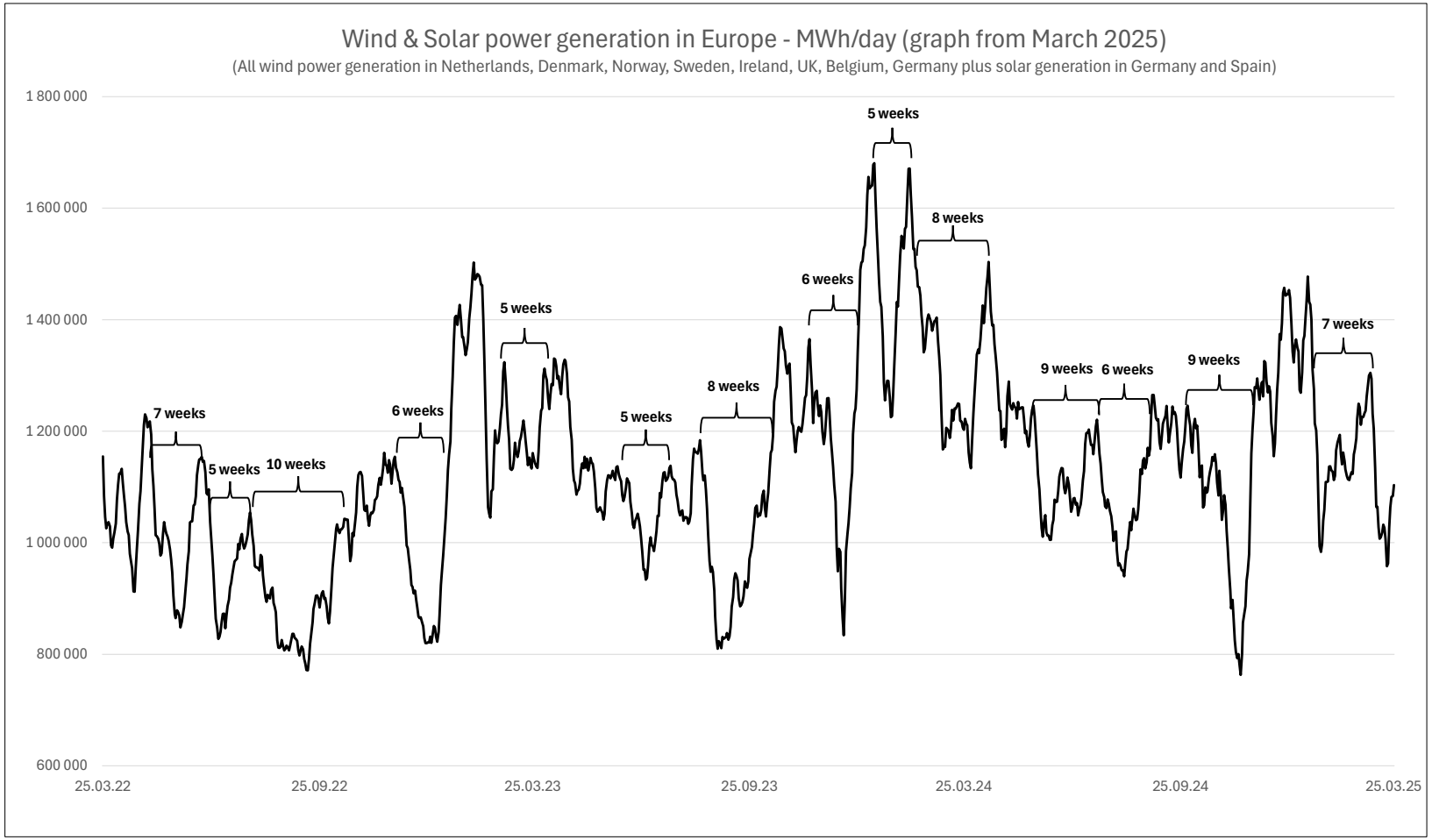
- Some probably think that we can live from solar in the summer and wind in the winter – in theory a good match





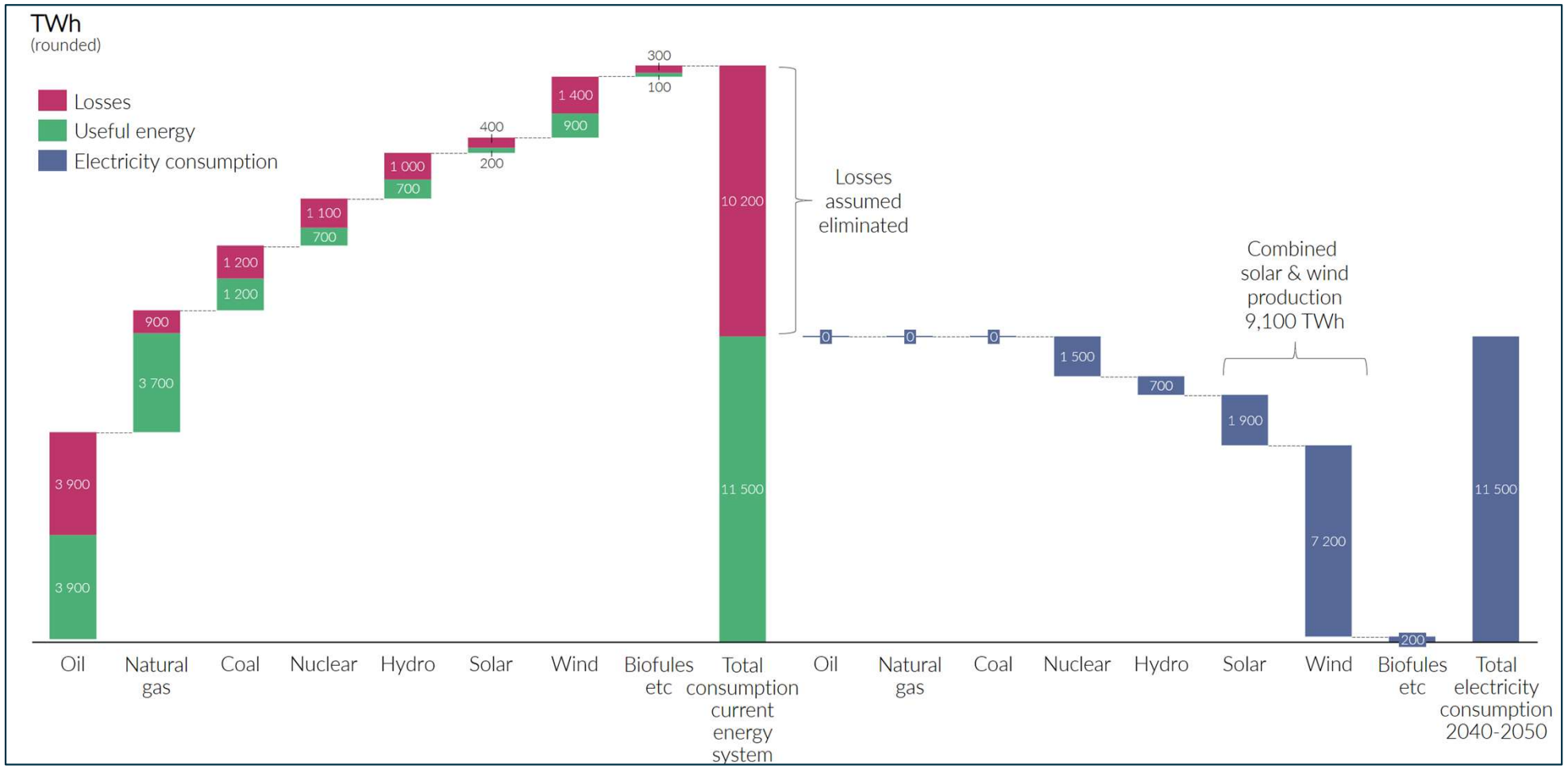
Let us put wind and solar together and see if they balance each other

- Could loose 600-800 GWh/day very quickly, so there is a need to fill in with something else



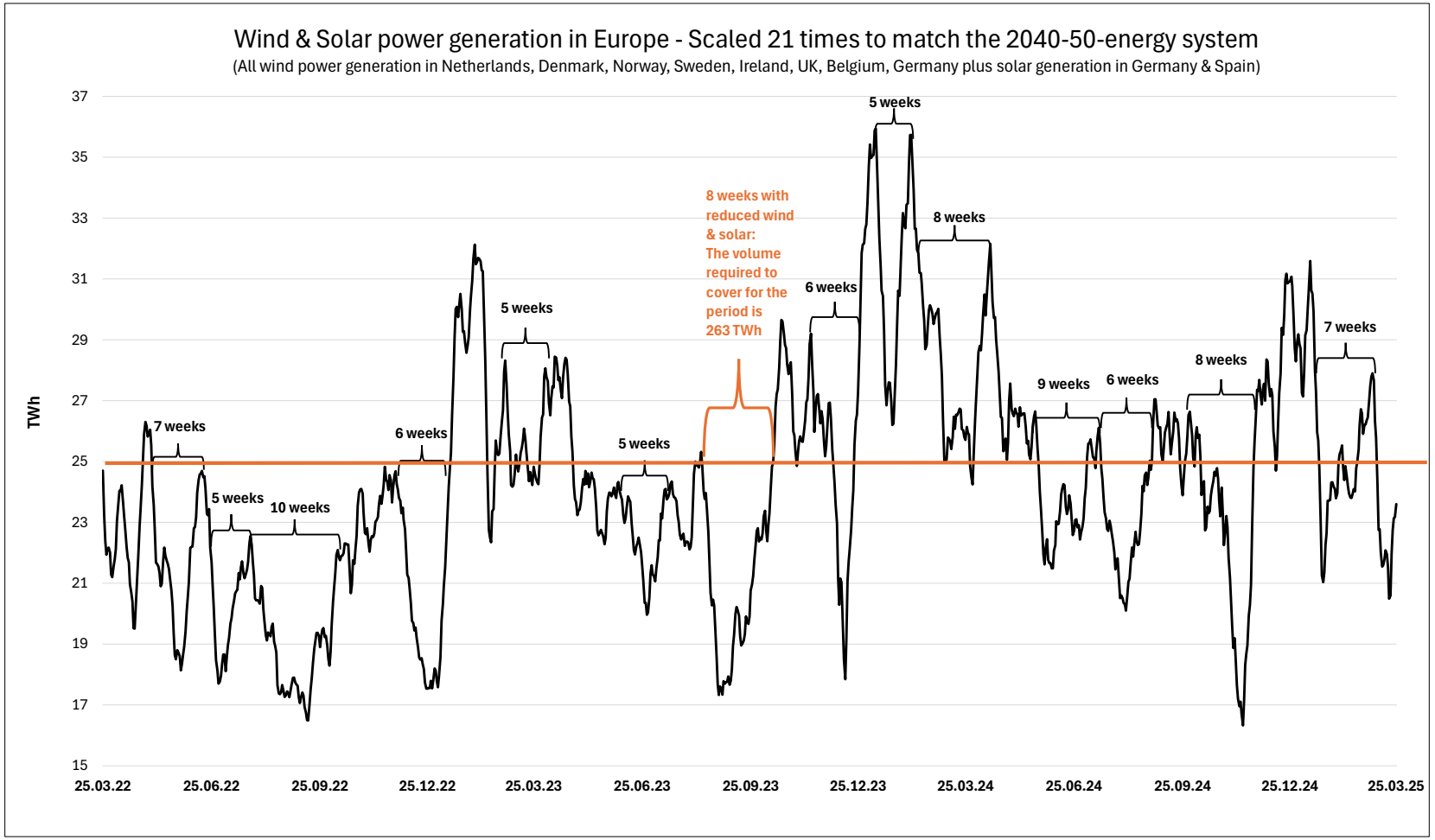
A new European energy system that moves to electricity will have lower losses

- It will require a massive increase in solar and wind power production, but how do we balance a Dunkelflaute in this system?



Let us scale the solar & wind-based system to 2040-50 to see what happens

- Just one “Dunkelflaute” would require 263 TWh of alternative power and the average annual replacement is 729 TWh



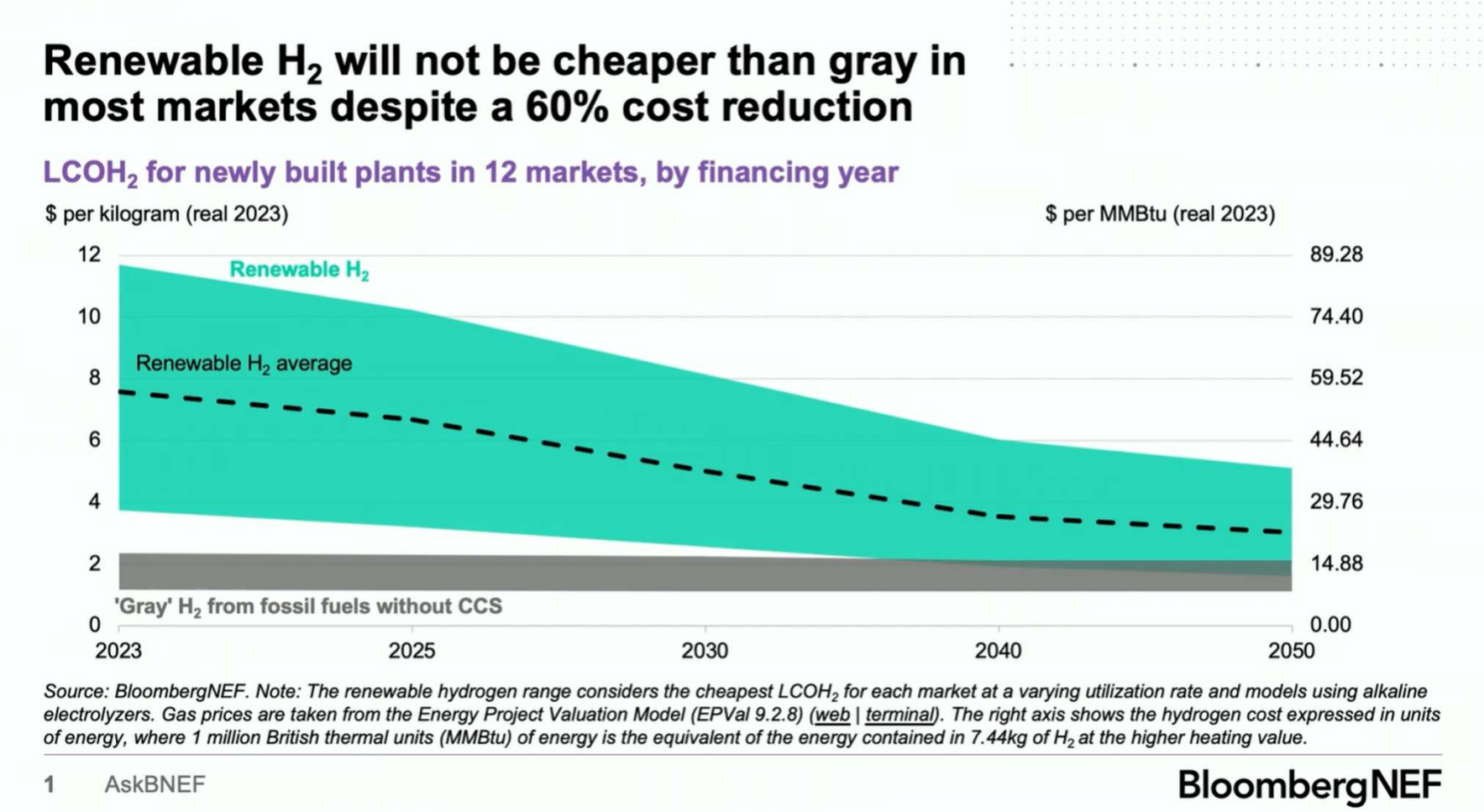
Natgas is the cheapest way to cover for “Dunkelflaute” in a 2040-50 system

- Batteries are way to expensive, even with 10 times lower costs' than today (8 trillion USD in CAPEX)
- Hydrogen is also way to expensive and would require 1.2 trillion in Electrolyser CAPEX alone
- Low CAPEX required for natgas to cover “Dunkelflaute” in a new 2040-50 system based on solar/wind
- CO2 emissions in Europe would be cut 94% (from 3.547 gigatons to 0.215 gigatons)

Europe 2040-50			
Annual solar/wind production in 2040-50	9 078	TWh	This is the power production of solar/wind required to reach climate targets in Europe
Solar land use 2040-50	21 938	km2	More than the land area of Slovenia (20 271 km2)
Land-use windpower 2040-50	210 853	km2	Almost the size of Romania (238 397 km2)
Solar/wind power production pr day in 2040-50	25	TWh	The daily volume of solar/wind production in the EU is almost a quarter of all annual norwegian power production
Number of minutes cover by battery capacity today	5,0	Minutes	Battery capacity in Europe today is 36 GWh
Annual battery capacity today if charge-discharge to 100% every day	13	TWh	If 36 GWh is charged and discharged 100% every day
Real life annual capacity if charged to 90% and discharged to 40% every day	7	TWh	You cannot on a daily basis charge and discharge 100%, must keep battery life
Daily lost solar/wind on observed two months "Dunkelflaute in autumn 2023	4	TWh	This volume of daily power output would be lost in 2040-50 with a Dunkelflaute similar to autumn 2023
Lost solar/wind on observed "Dunkelflaute in autumn 2023	263	TWh	This is lost total in a two month Dunkelflaute and would be extremely expensive to cover with batteries
How much must battery capacity increase to cover for a Dunkelflaute similar to autumn 2023?	7 311	Times	You need to increase battery capacity in Europe by 7,311 times to cover for a Dunkelflaute in 2040-50, assuming you know when dunkelflaute starts
Installed Grid Scale Batteries in Europe currently	9	GW	This is installed GW of grid scale batteries in Europe
Required amount of GW installed by 2040-50 to cover a Dunkelflaute	65 795	GW	This is the amount of installed battery capacity needed to cover a Dunkelflaute in 2040-50
Utility system battery storage cost (This is much more than just the cost of the battery cell)	300	USD/KWh	Based on BNEF estimates of turnkey energy storage system prices in Europe for 2025 and added EPC, grid connection, developer costs
Cost USD per KW Utility Scale Battery Storage - 4 hour battery	1 200	300 USD/KWh	Based on BNEF estimates of turnkey energy storage system prices in Europe for 2025 and added EPC, grid connection, developer costs
Total CAPEX in batteries to cover a Dunkelflaute in 2040-50	**79**	**Trillion USD**	**European total annual GDP is 20 trillion USD, about the same as the total Norwegian oil fund**
Total CAPEX in batteries if battery costs are cut 10 times	**8**	**Trillion USD**	**Still way too expensive for Europe, even with total battery system costs down to 30 USD/KWh**
Power generation required to cover for solar/wind below the daily average in 2040-50	**729**	**TWh**	**This is the average required output of power needed annually to cover for wind/solar below 25 TWh per day (which is the daily avg demand in 2040-50)**
Hydrogen needed to cover for lack of wind/solar in 2040-50	43	Million tonnes	Assuming you loose 50% of the energy in the hydrogen when converted to electricity
Cost per KW installed electrolyser capacity in US/Europe	2 500	USD/KW	This is the BNEF calculation of the cost for electrolysers in Europe/USA
How many GW of electrolysers need to be installed to cover for lack of solar/wind in 2040-50	475	GW	Assuming 70% efficiency of the electrolysis process to produce Hydrogen and then 50% utilization of the electrolyser (using combo solar/wind)
Capex required in electrolysers in Europe to cover for lack of solar/wind in 2040-50	**1 188**	**Billion USD**	**This is the CAPEX cost for the electrolysers, in addition you need to build the wind/solar to generate the power for the electrolysis**
Solar and wind production required to produce the required hydrogen in 2040-50	1 041	TWh	Assuming 30% of the energy is lost when transforming electrons to Hydrogen
Installed solar capacity in GW to generate half of the required hydrogen in 2040-50	396	GW	Assuming 15% utilization of installed solar capacity
Installed wind capacity in GW to generate half of the required hydrogen in 2040-50	198	GW	Assuming 30% utilization of installed wind capacity
CAPEX in solar to install capacity to produce power for hydrogen production	**595**	**Billion USD**	**Assuming 1,500 USD/KW, based on 2024 EIA report for solar PV with single axis tracking (without tracking is more expensive)**
CAPEX in wind to install capacity to produce power for hydrogen production	**295**	**Billion USD**	**Assuming 1,489 USD/KW, based on 2024 EIA report for onshore wind**
Total CAPEX for solar/wind/electrolysis to cover for low solar/wind in 2040-50	**2**	**Trillion USD**	**Remember this is only the CAPEX, if the price of the power needed for electrolysis is not free this cost needs to be added**
Total CAPEX if hydrogen can be produced when there is too much solar/wind	**1,2**	**Trillion USD**	**In this case one can utilize all the extra power from when the solar/wind is above the average daily demand**
Required installed GW natgas plant to cover for lack of solar/wind in 2040-50	159	GW	Natgas power plants assumed utilized 229 days per year (5,496 hours, or 63%) to generate 729 TWh, adding 20% capacity to cover for maintenance
Current installed natural gas based power plant capacity in Europe	406	GW	This is BNEF data for 2023
Less needed GW of power production capacity from natgas in 2040-50	**247**	**GW**	**In 2040-50 Europe would need less netural gas based capacity than today, since natgas only covers when lack of sun/power**
Estimated OPEX annually for natural gas power generation in 2040-50	91	USD/MWh	Assumed 25 EUR/MWh gas price (the same as about 8 USD/MMBTU) and 100 EUR/tonne CO2 price for burning natgas
TOTAL annual OPEX in producing power from natural gas when lack of solar/wind	**66**	**Billion USD**	**This is the annual cost of operating power plants running on natural gas, incl the cost of natgas, CO2-price and maintanance**
Annual needed amount of natural gas to produce power when lack of solar/wind	125	BCM	Assuming you loose 50% of the energy in the natgas when converted to electricity
Total Norwegian production of natural gas in 2024	126	BCM	Norwegian production of natural gas in 2024 would just cover the 2040-50 European need, but how do we keep production at this level?
Total European natgas demand in 2023 (Energy Institute data for Europe)	463	BCM	Most of this consumption is for industry and heating (buildings) - power generation is only 20% of the usage of natural gas in Europe
Reduced demand for natural gas by 2040-50 in Europe in %	73 %	Percent	The only consumption left of fossil fuels in Europe would then be natural gas to generate power when the solar/wind production drops
Reduced CO2-emissions in Europe from 2023-2045 in the new system by using natgas to cover	**94 %**	**Percent**	**Europe emitted 3.547 gigatonnes CO2 from energy in 2023, in 2045 with the above system emissions would be 0.215 gigatonnes so cut by 94% (unabated)**

Green Hydrogen is NOT the cost efficient solution to cope with Dunkelflaute

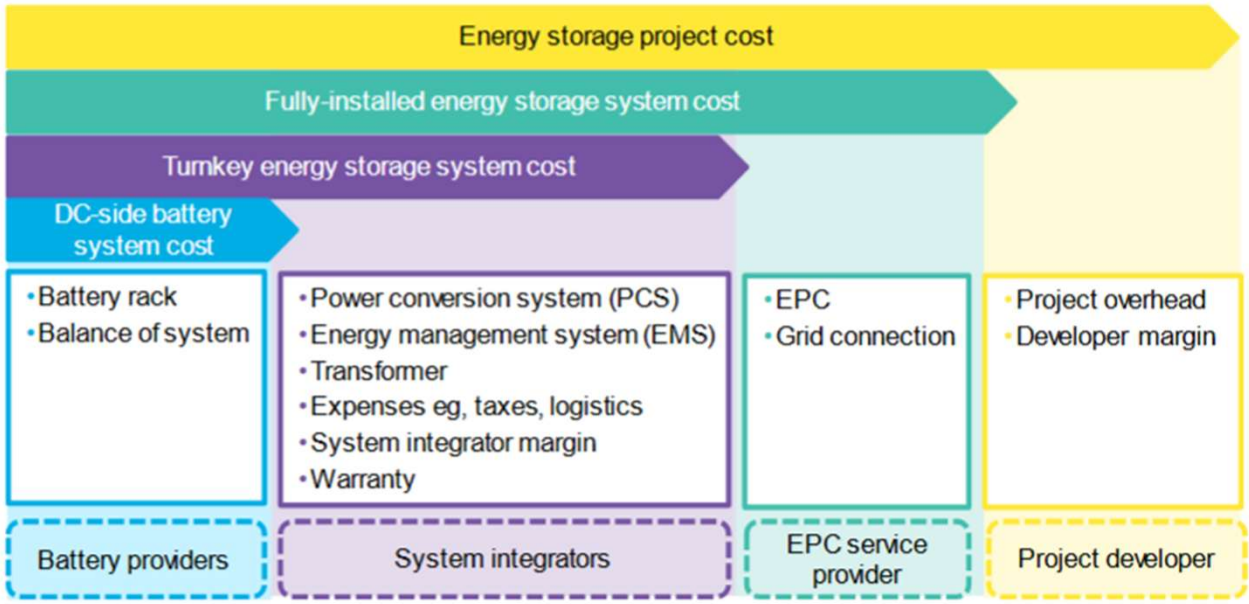
- Green Hydrogen can be used to cope with Dunkelflaute but will be many times more expensive than natural gas



Do not mix the cost of battery cells with the total system cost for batteries

- When we calculate the CAPEX for using batteries to cover Dunkelflaute we must include more than battery cell prices

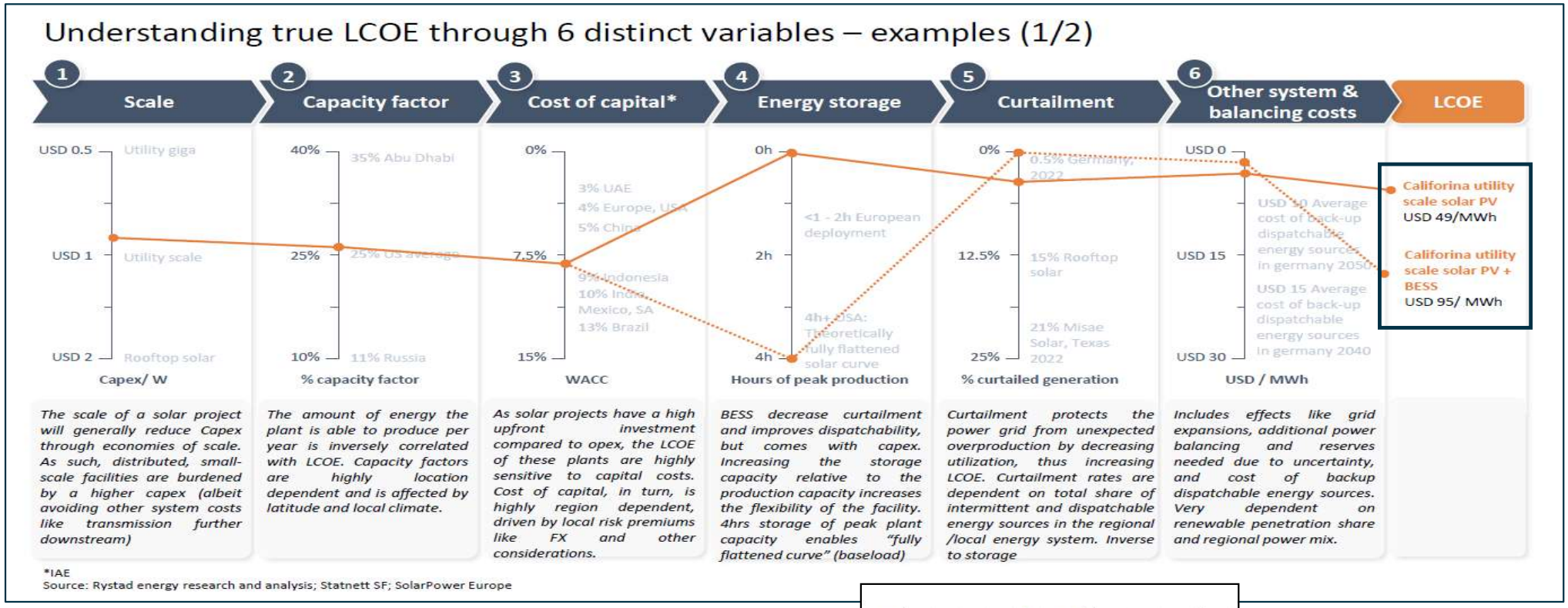
Figure 3: Energy storage system cost structure, inclusion and major service providers across each segment

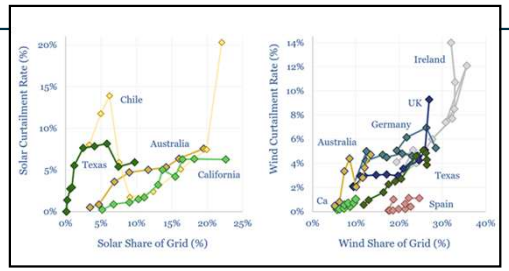


Source: BloombergNEF. Note: EPC and grid connection services provided by the system integrator or third-party EPC service provider, depending on the project scale and complexity. Medium-voltage transformers are included in turnkey energy storage systems. High-voltage equipment is typically included in fully-installed energy storage systems. More detailed breakdown and definitions available in Appendix A.

Cost for solar including capacity factor, storage, cost of capital, etc

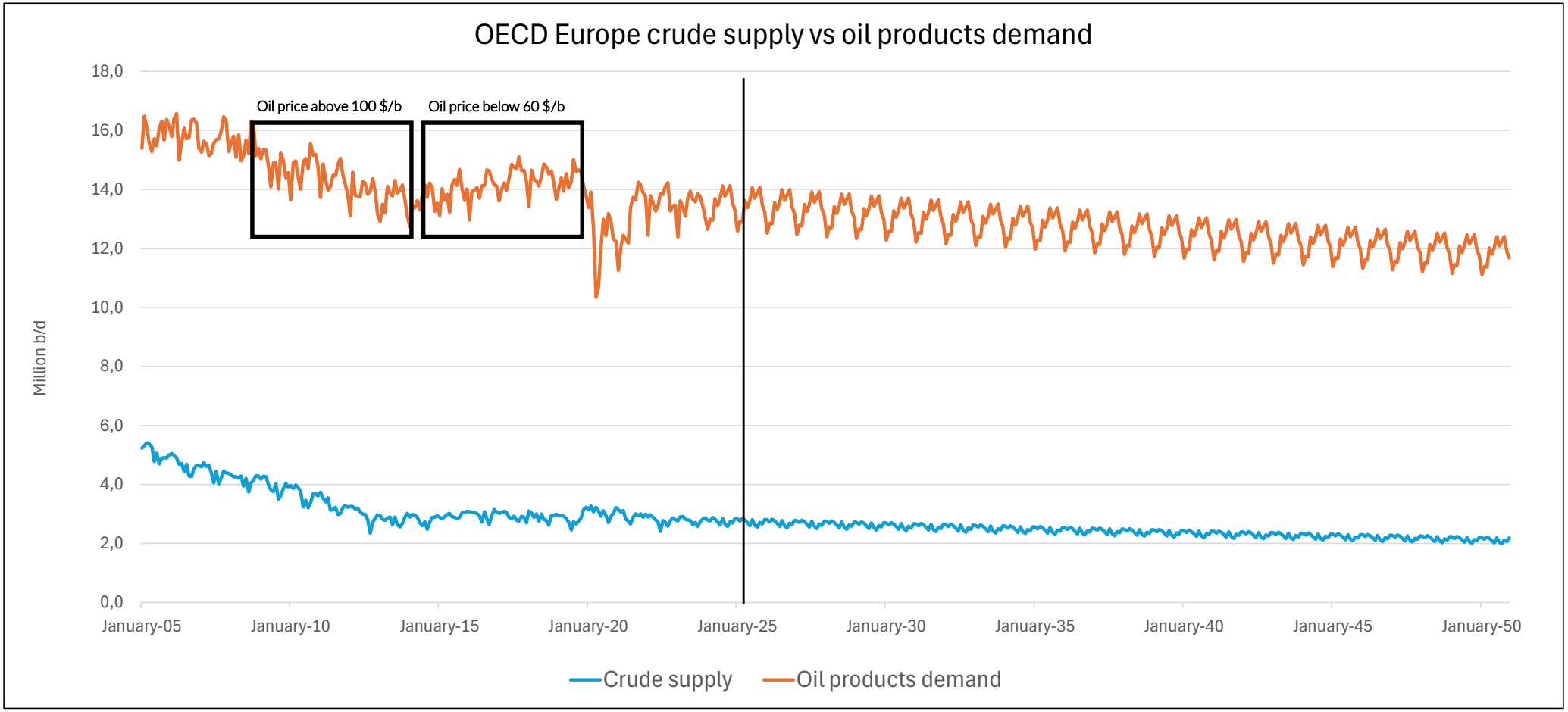
- Solar power in California for example becomes much more expensive if we include storage costs





Europe has an immensely difficult starting point for energy self sufficiency

- Only one 5th self sufficient for oil consumption and oil demand is at the same level as 10 years ago despite EV sales…



Europe is short natural gas in all scenarios

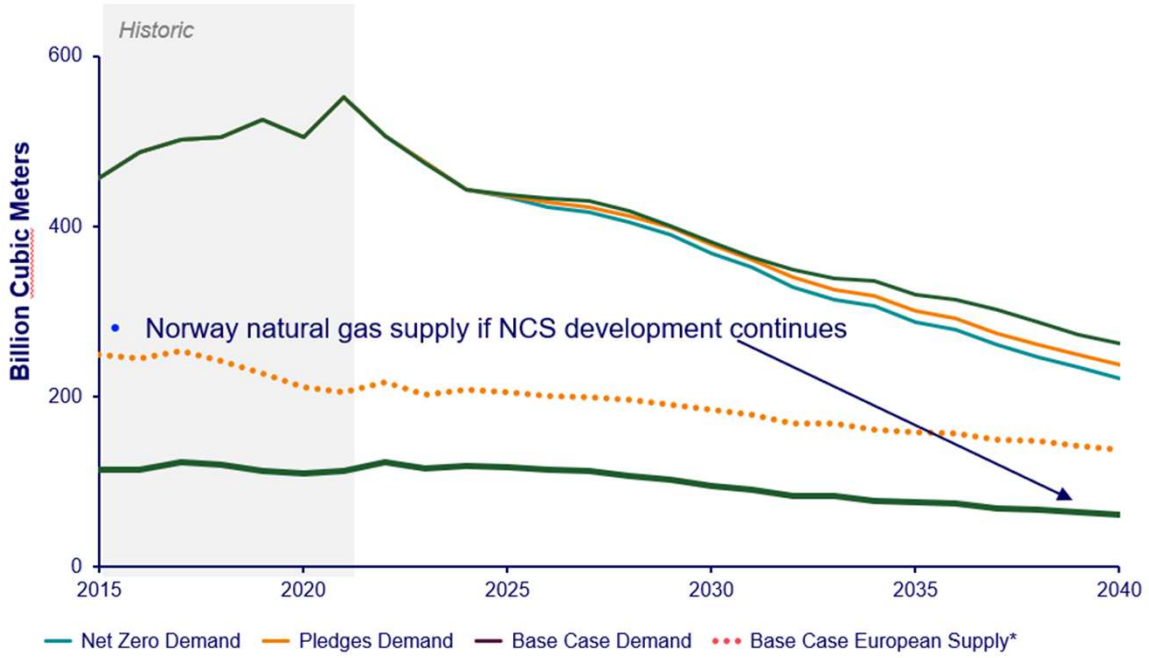
- The starting point for natural gas consumption is Europe is dramatic, being only two fifths self-sufficient

Report: Norway Emissions Analysis

Under all three WoodMac scenarios, Europe is a net natural gas importer

Europe is only 2/5th self sufficient for natural gas

EU27+UK Gas Demand and European Supply



Outlook	Global Trajectory
Base case	Consistent with 2.5 ˚C global warming
Pledges scenario	Consistent with below 2 ˚C warming (global Net Zero by 2060)
Net Zero 2050 scenario	Consistent with 1.5 ˚C warming (global Net Zero by 2050)

Wood Mackenzie

Source: Wood Mackenzie, 2023 Energy Transition Outlook.

*European supply includes Norwegian production

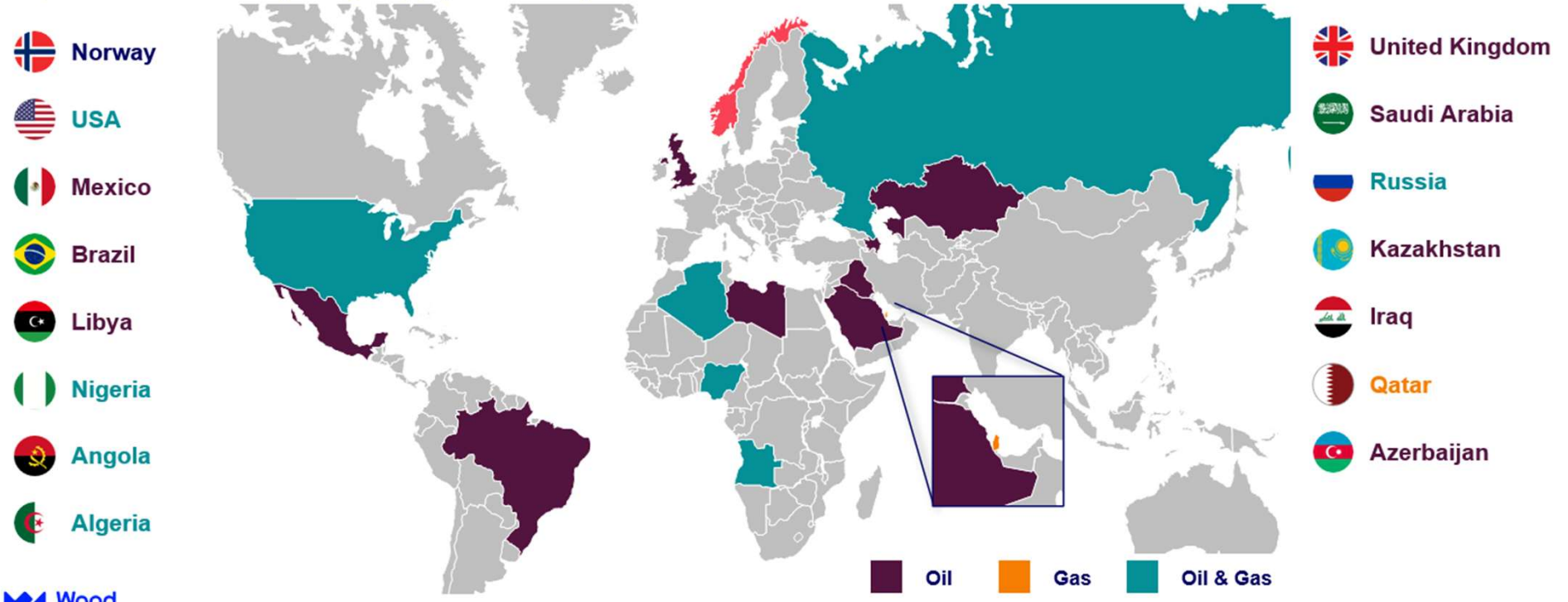
13 countries (in addition to UK and Norway) supplies Europe with oil & gas

- These are countries from Americas, Middle-East, Africa & Russia

Based on our market analysis, we have identified 15 key sources of oil and gas supply (including Norway) into Europe that we have benchmarked in the emissions assessment

These countries are the largest sources of oil, piped gas and LNG supply to Europe in 2022/23

Map of identified competing supply into Europe



Wood Mackenzie Source: Wood Mackenzie.

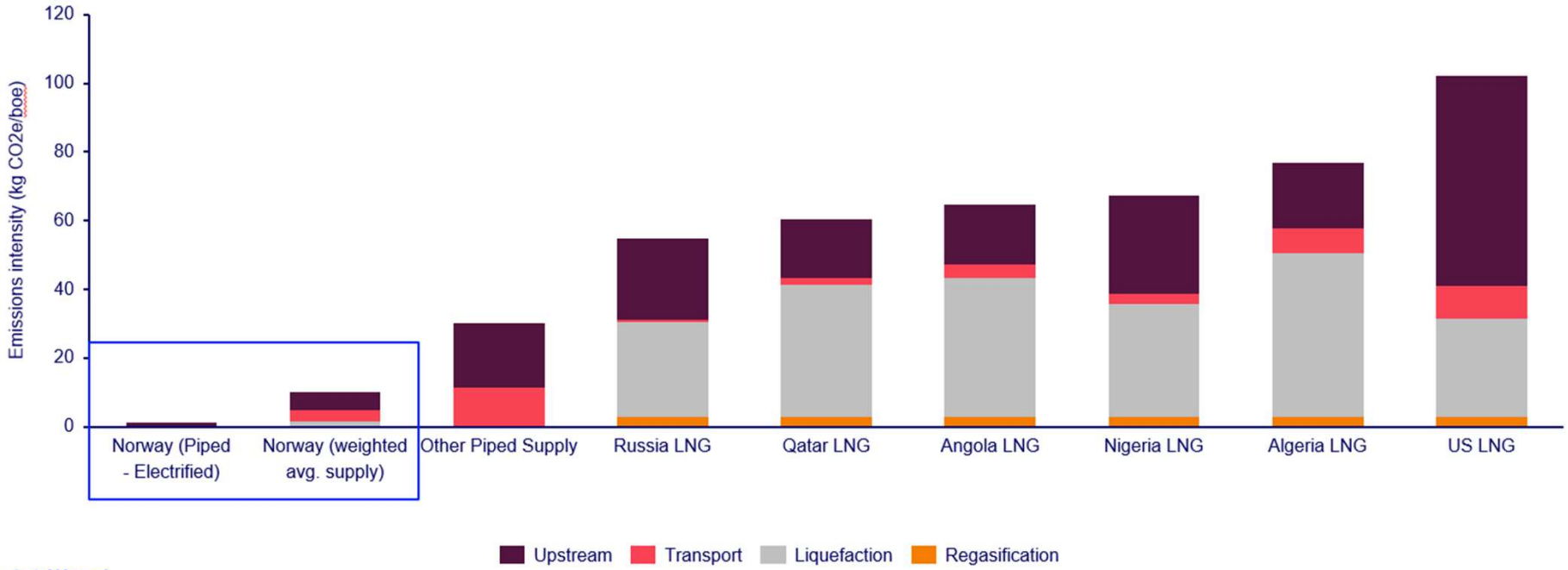
For natural gas Norway has, BY FAR, the lowest upstream emissions

- Norway has by far the lowest emissions from natural gas, even when the LNG is included

Similarly, Norway has the lowest average emissions intensity for weighted average gas supply into Europe

The US LNG upstream emissions suffer from the very dispersed nature of the production and gathering system

Emissions intensity for key supply countries into Europe, 2024 - Gas



Wood Mackenzie

Source: Wood Mackenzie. Upstream emissions intensity based on country weighted average. Transport based on LNG delivered into Rotterdam using most popular routes into Europe from supply country. Regas emissions based on emissions from GATE in Rotterdam. For full methodology see appendix.

Energy security is important to Europe but so is climate policy

- **But even climate policy suggest Norway should develop its shelf and not close it down**

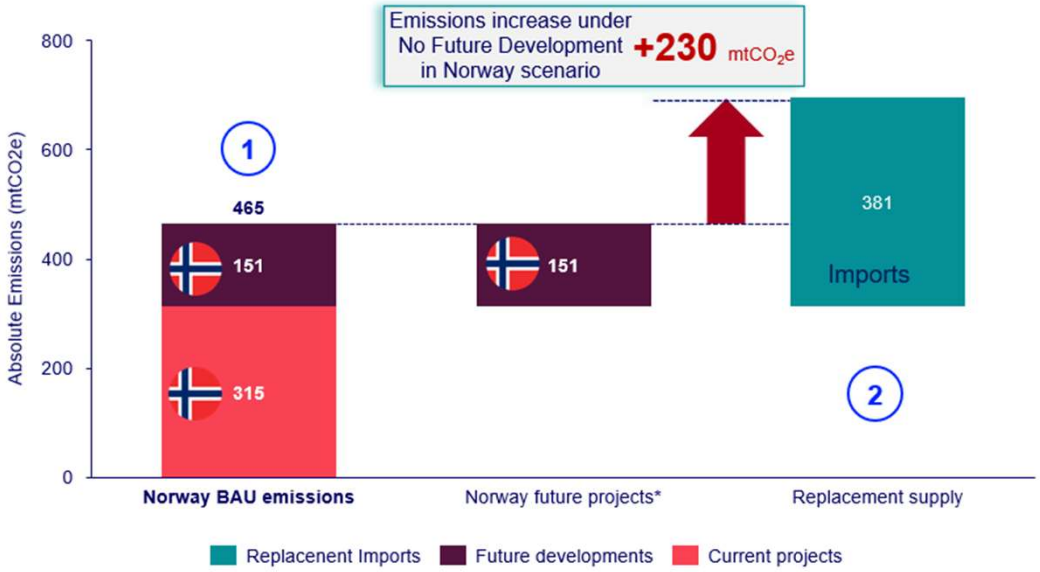
Report: Norway Emissions Analysis

Replacing production from future Norwegian developments with imported volumes results in an emissions increase of 230 million tCO_2e between 2024 and 2040

This is driven by the higher upstream, midstream and transport emissions of imported volumes

Emissions impact of no future developments in Norway 2024-2040

Cumulative absolute emissions from 2024 - 2040



Assumptions

- Includes upstream, transport and midstream emissions for oil & gas
- Oil & gas volumes are replaced on 1:1 basis, whereby Norwegian oil & gas supply is replaced by the same volume of imported oil & gas
- Replacement import volumes have been allocated on a pro-rata basis i.e. based on current oil & gas imports into Europe, keeping constant out to 2040

Wood Mackenzie

Source: Wood Mackenzie, Q1 2024.

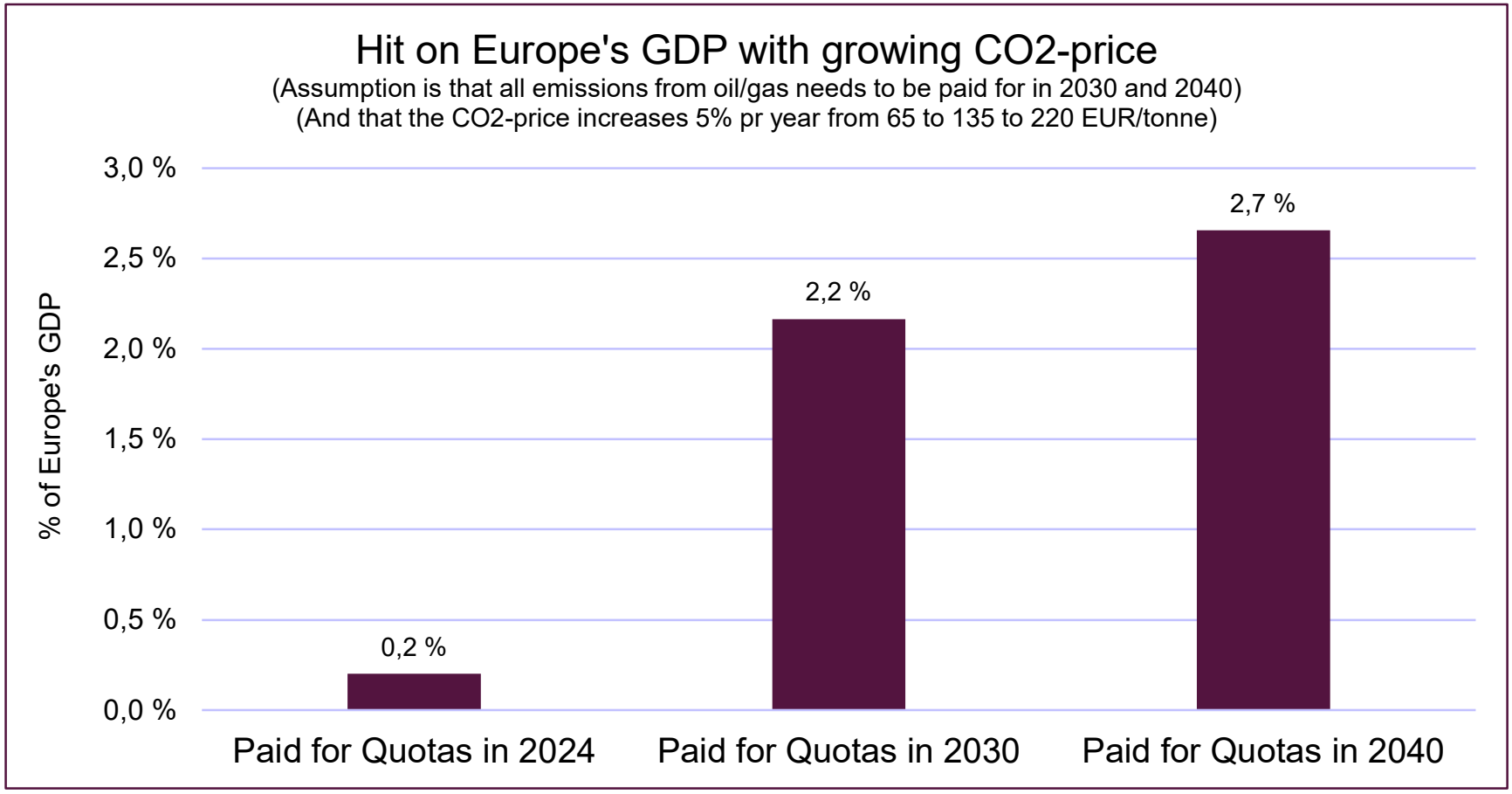
*Includes pre-FID and future discoveries (Yet-to-Find (YTF))

35

What happens to Europe's economy if only EU increase the cost of CO2

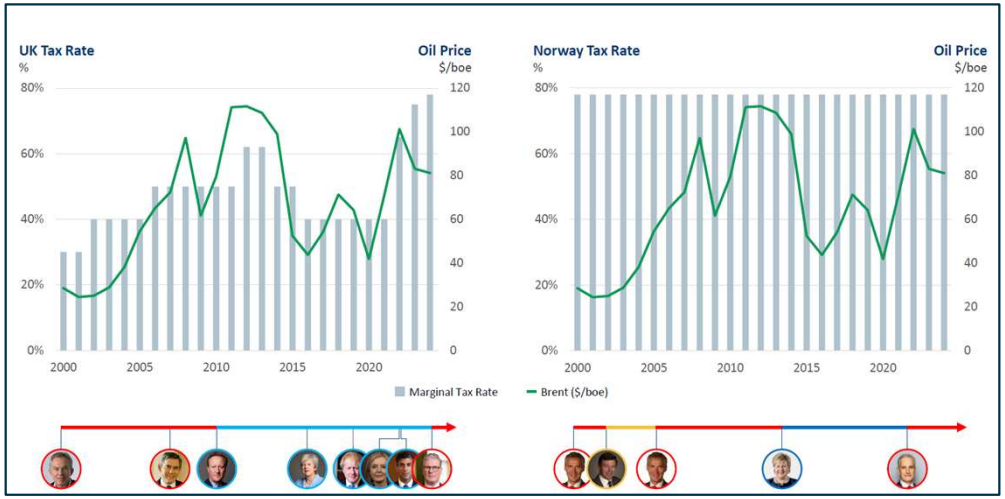
- **Using WoodMac base case for European oil/gas demand the hit to the economy could be very high**

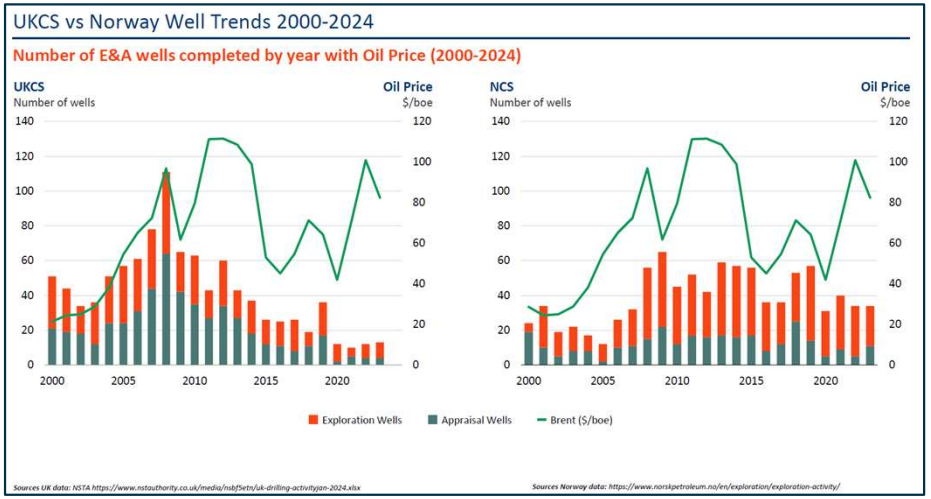
It will be very costly for Europe if Europe walks alone on growing CO2-prices:

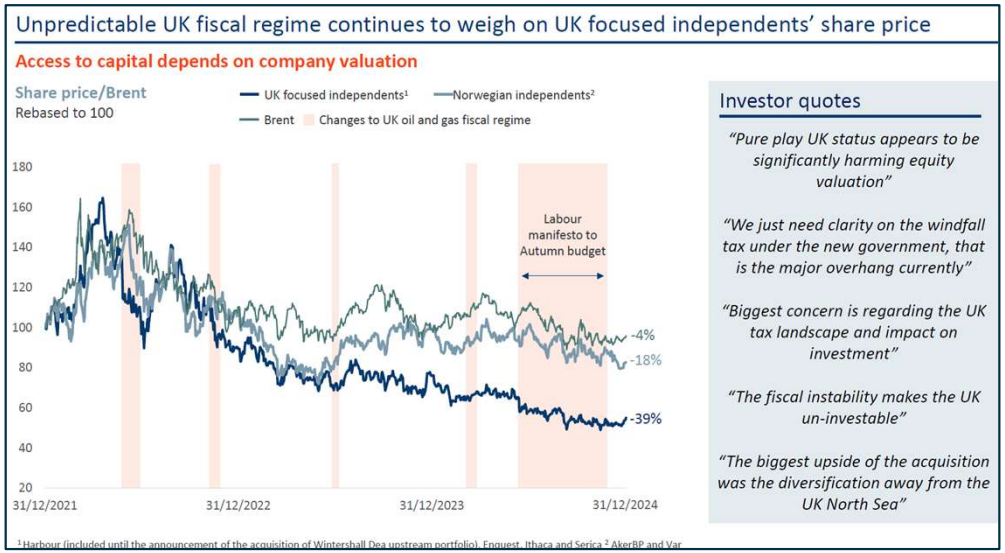


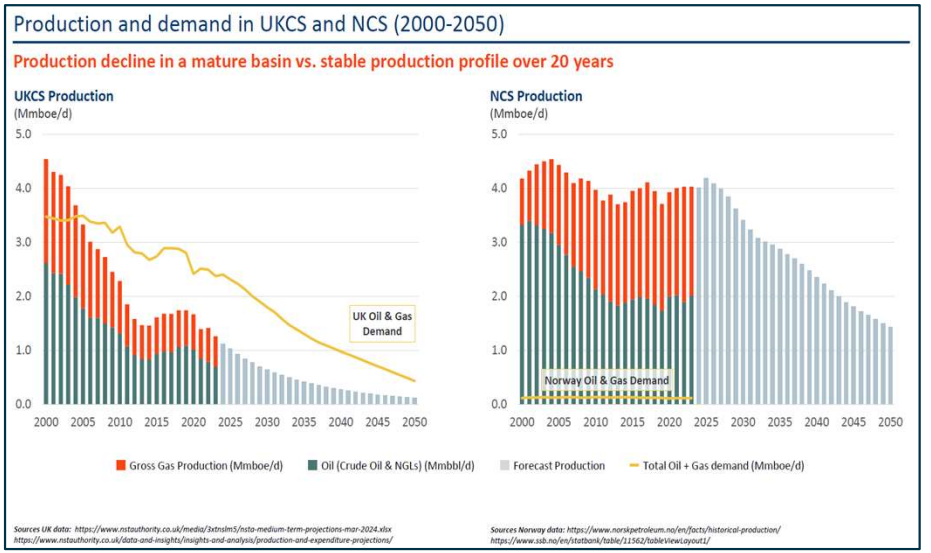
Fiscal instability is very bad for investments and hence production

- The UK turned from self sufficient to growing import dependence and it will only get worse



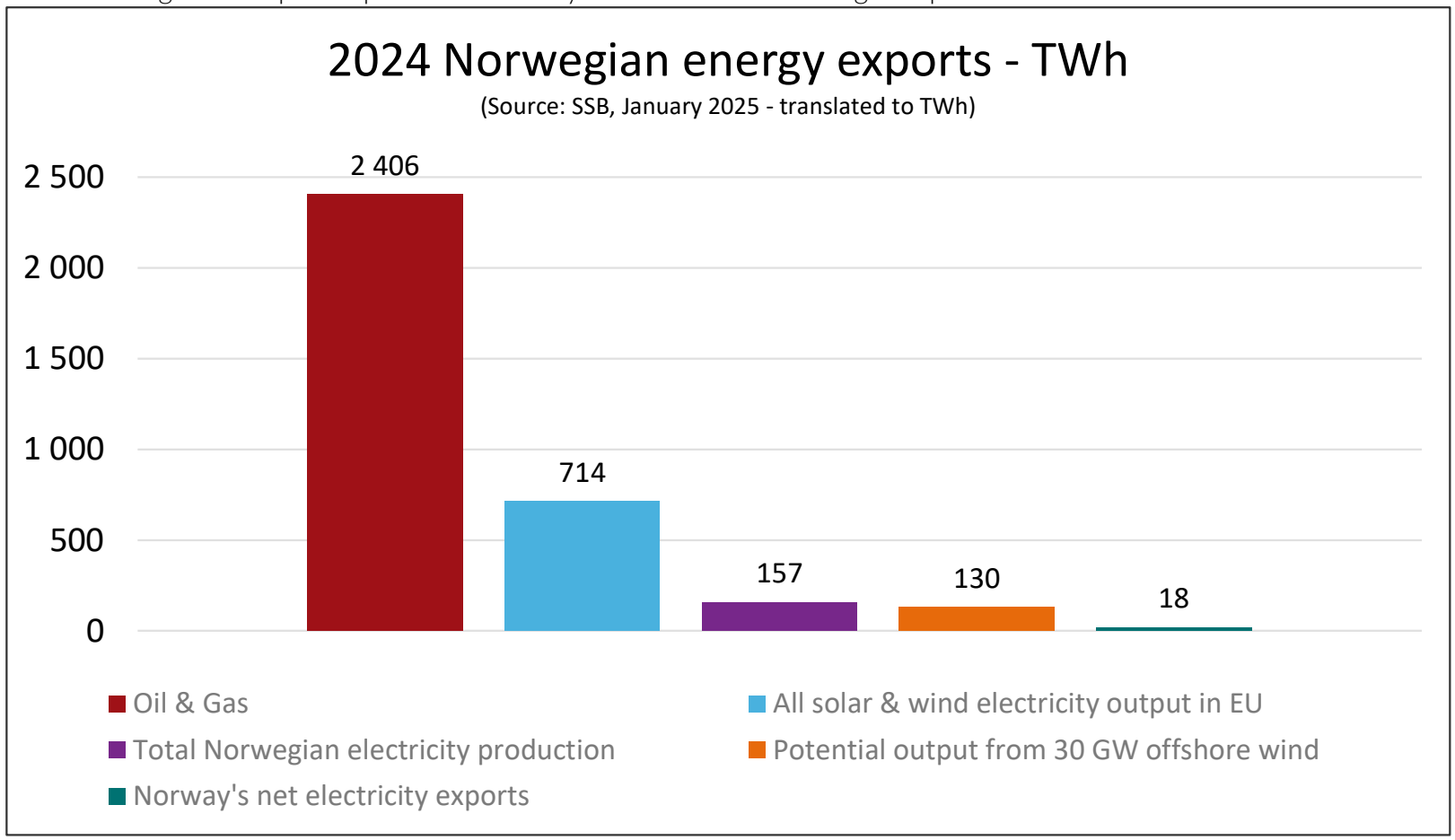






Norway contributes with more energy to Europe than all solar and wind energy put together

- Norwegian total power production is only a fraction of the oil & gas exports



Source: Statistical Bureau of Norway, BloombergNEF

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