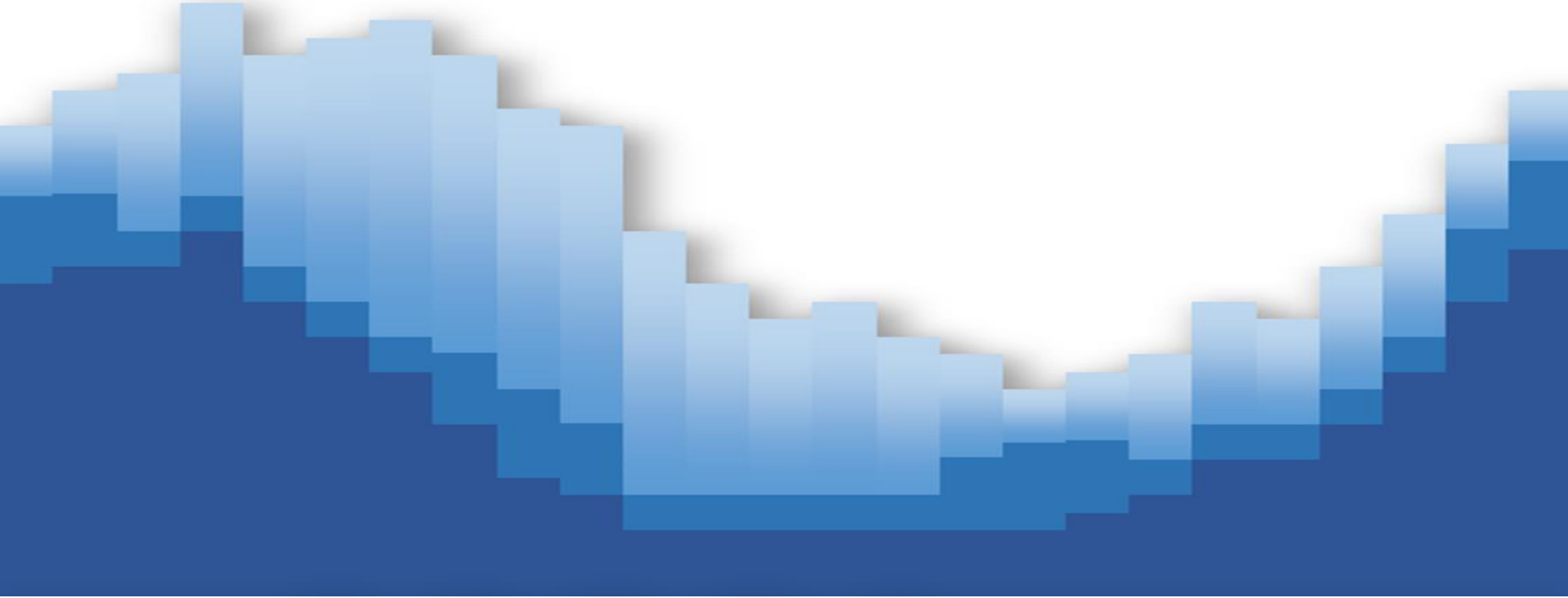
Will Geology catalyze Europe's next Energy Transition?



100 JAAR GEOLOGIE IN KAART

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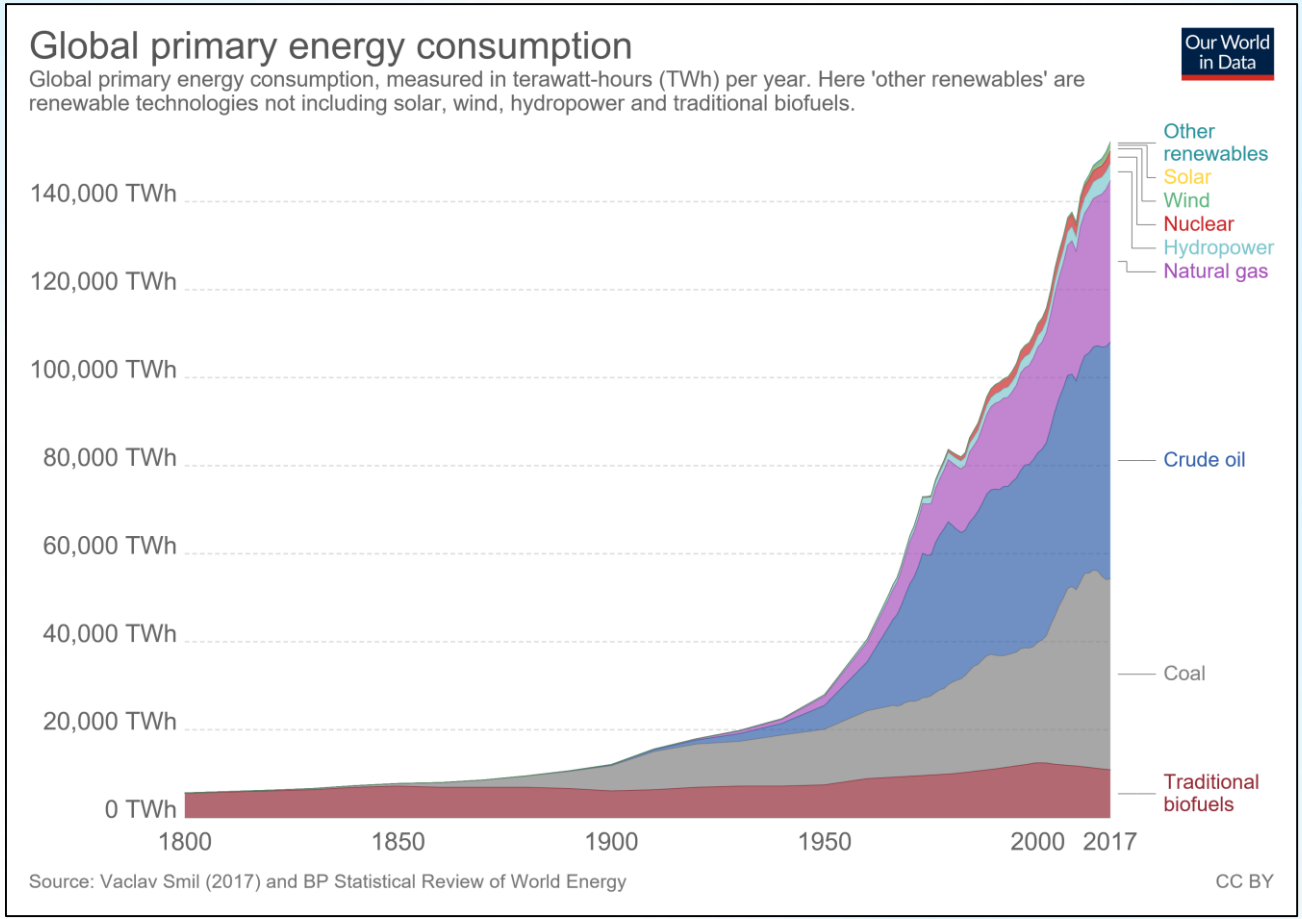
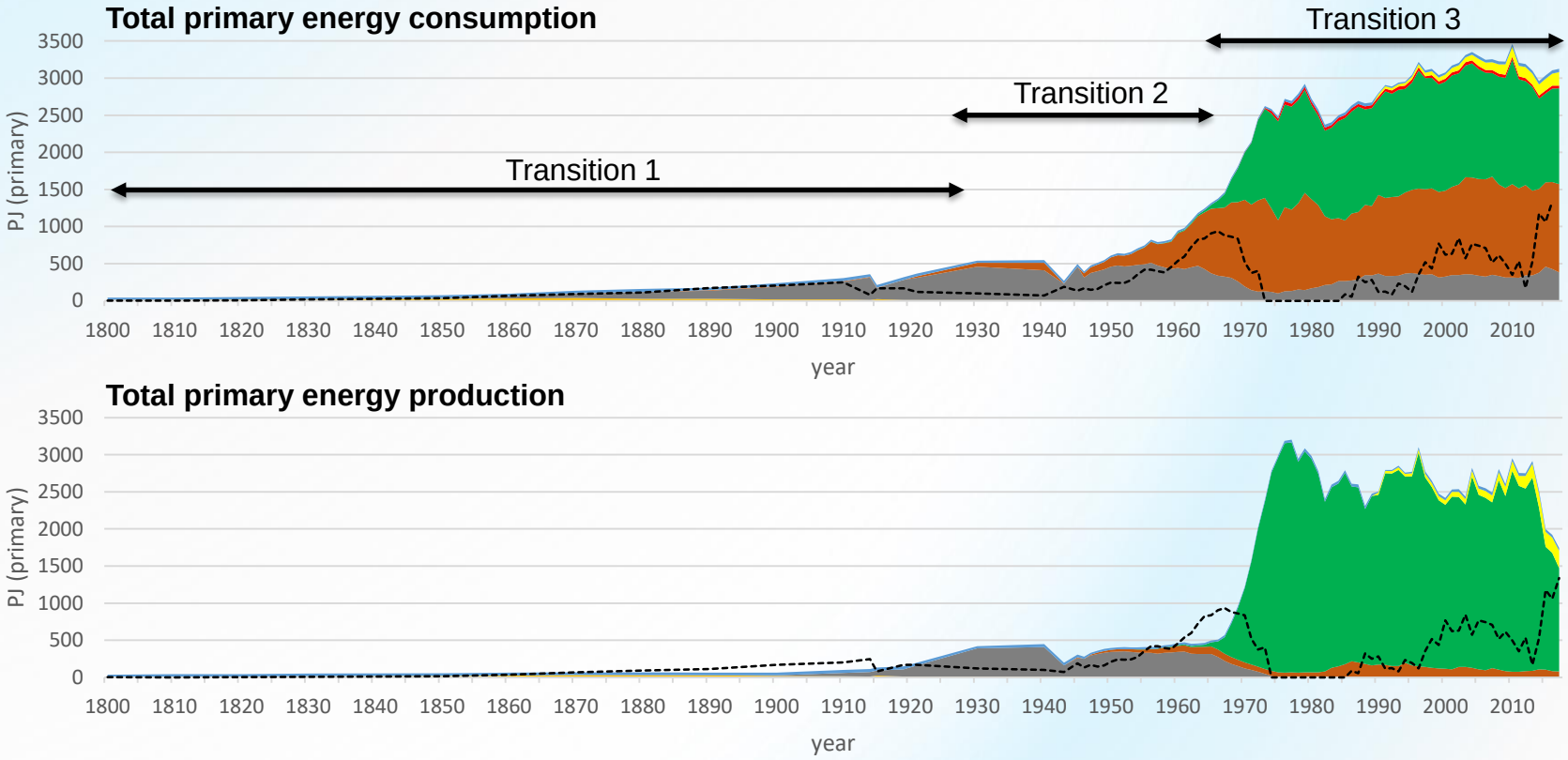
Long run primary energy consumption, Global

(downloaded from ourworldindata.org)



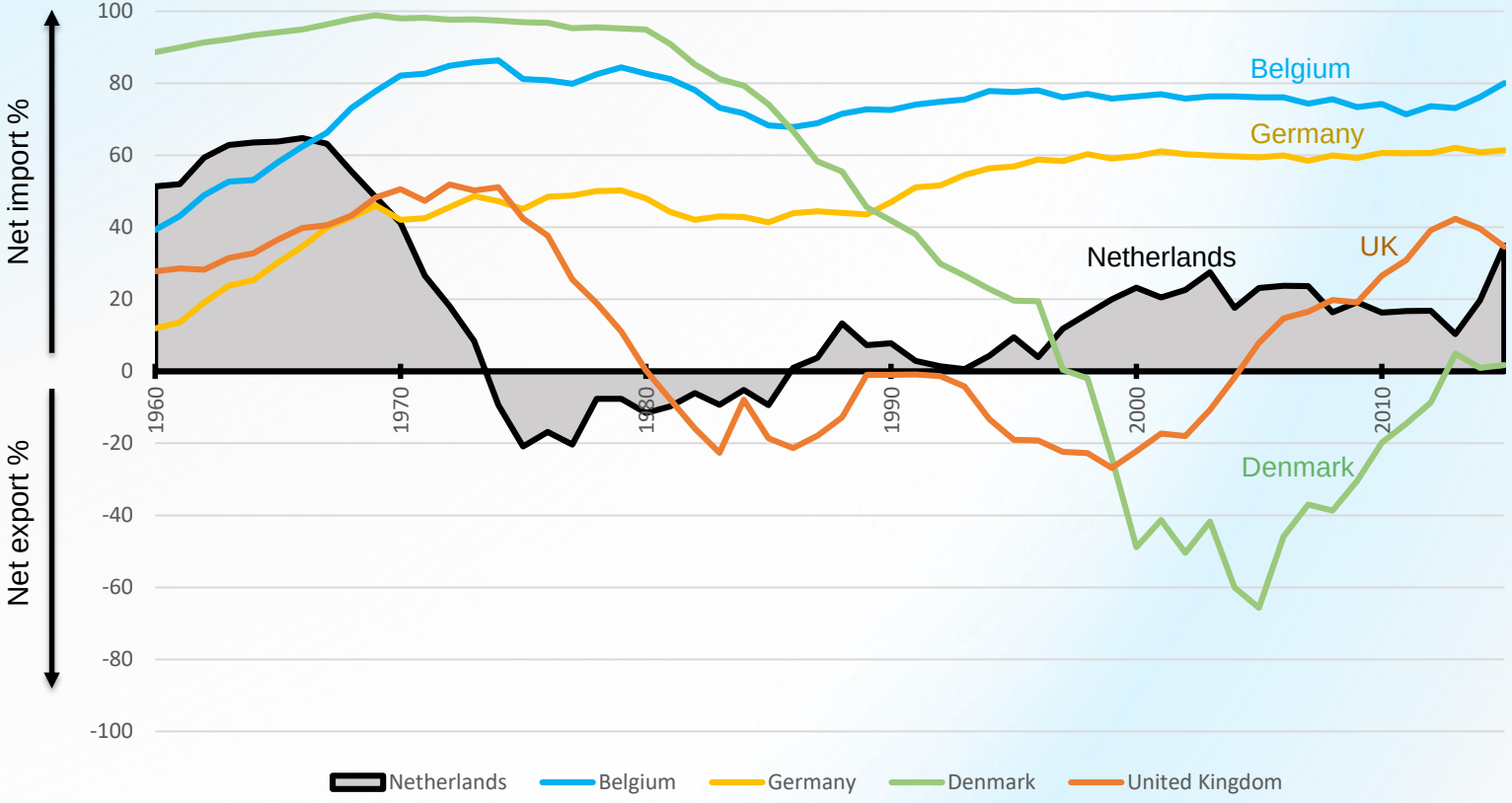
Long run primary energy statistics, Netherlands

(Based on CBS Statsline 2019, J.W. Schot et al., 2000, Techniek in Nederland in de 20ste eeuw, own analyses)



Net import / export (% of primary energy use)

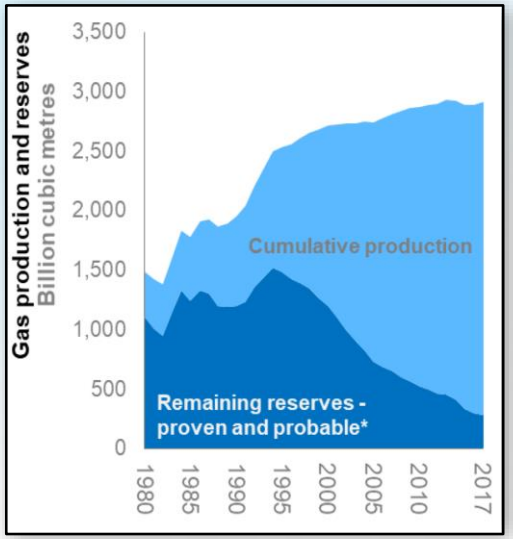
(based on World Bank, 2018)



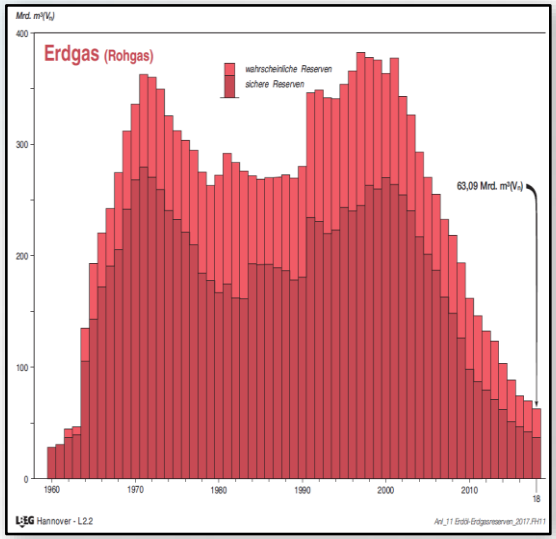
Energy trends in surrounding countries

Natural gas production profiles in surrounding countries (sources 2018: BEIS-UK, LBEG-DE, DEA-DK)

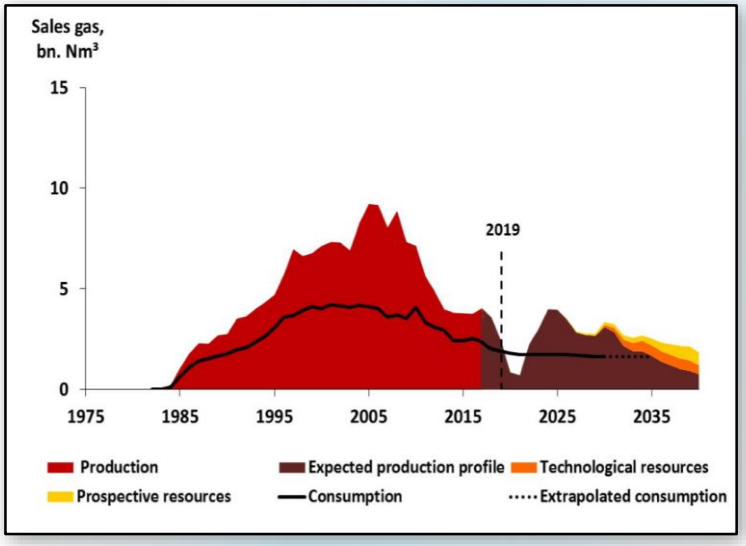
UK



Germany



Denmark



- Hydrocarbon decline NW EU countries
- Decommissioning of coal - lignite - nuclear → natural gas (bridge fuel) !
- Rate of renewable development?

- Shared Import dependency (e.g. from Norway, Russia, LNG) ?
- Flexibility and (renewable) exchange capacities ?

Development of import dependency, Netherlands

Based on CBS Statsline 2019, CE-Delft/Netbeheer 2017, MEA 2017 Energie Akkoord, Jaarboek delfstoffen/aardwarmte 2017

Example Scenario 1

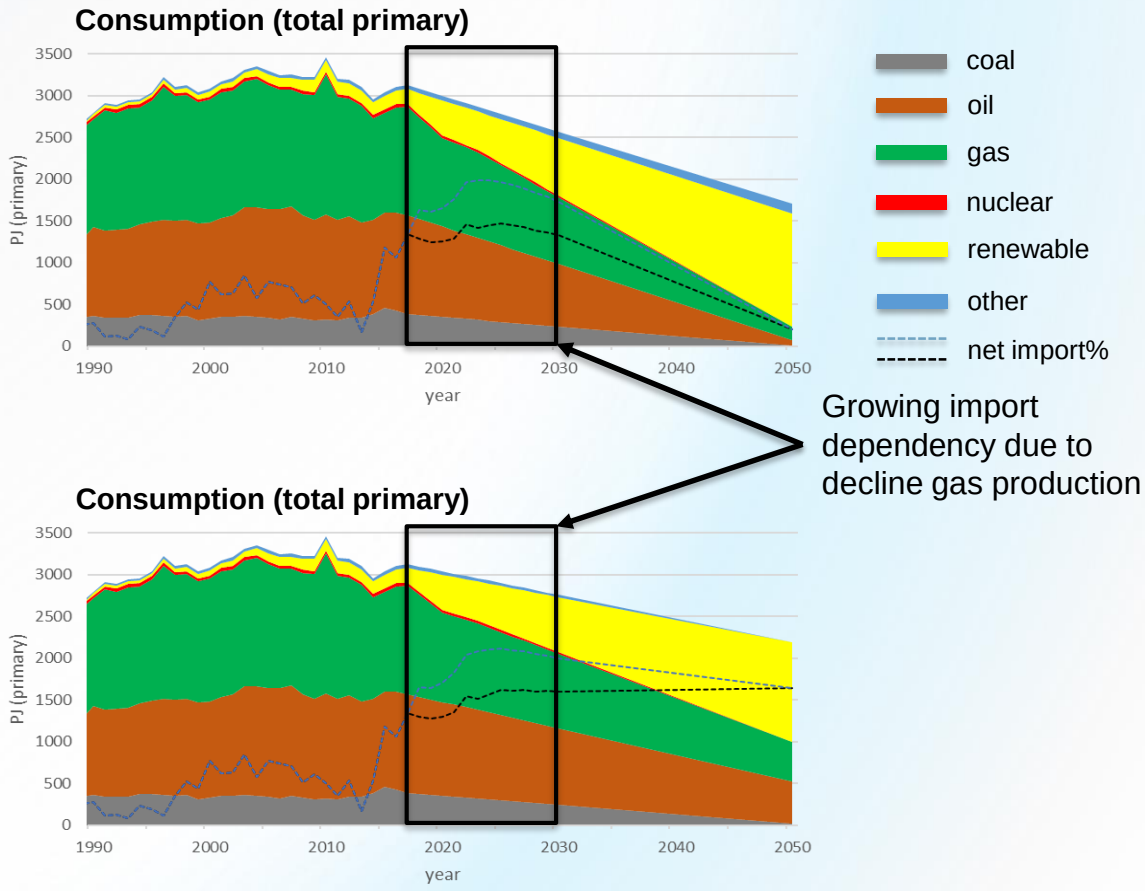
Wind & Solar

High domestic supply
Reduced diversity (electrification)
Reduced base load (intermittency)
Dependency: Balancing / Security

Example Scenario 2

Green Gas, Bio-fuels, H_2

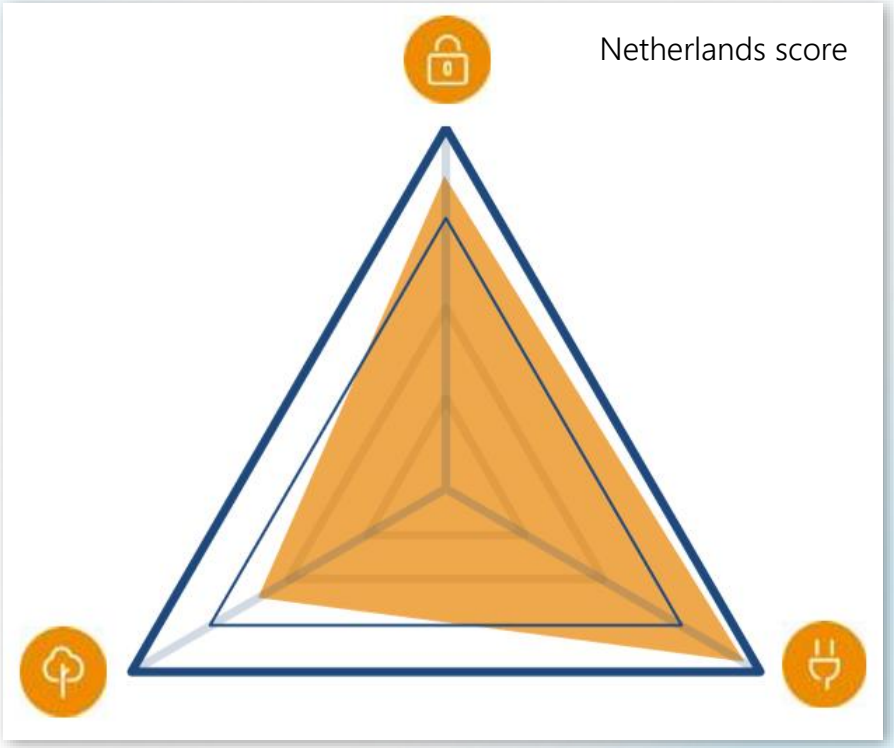
Low domestic supply
Diversity: Electricity / Gas / Bio
Preservation of base load
Dependency: Supply / Strategic



Energy Trilemma Index

(World Energy Council, 2018)

Security / Delivery



Environmental Sustainability

Equity / Affordability

Energy Trilemma Challenges: Security

(World Energy Council, 2018)

Dimension	%	Indicator category		%	Indicator		%
Energy security 	30%	1	Security of supply and energy delivery	15%	a	Diversity of primary energy supply	5.0%
					b	Energy consumption in relation to GDP growth	5.0%
					c	Import dependence	5.0%
		2	Resilience	15%	a	Diversity of electricity generation	5.0%
					b	Energy storage	5.0%
					c	Preparedness (human factor)	5.0%

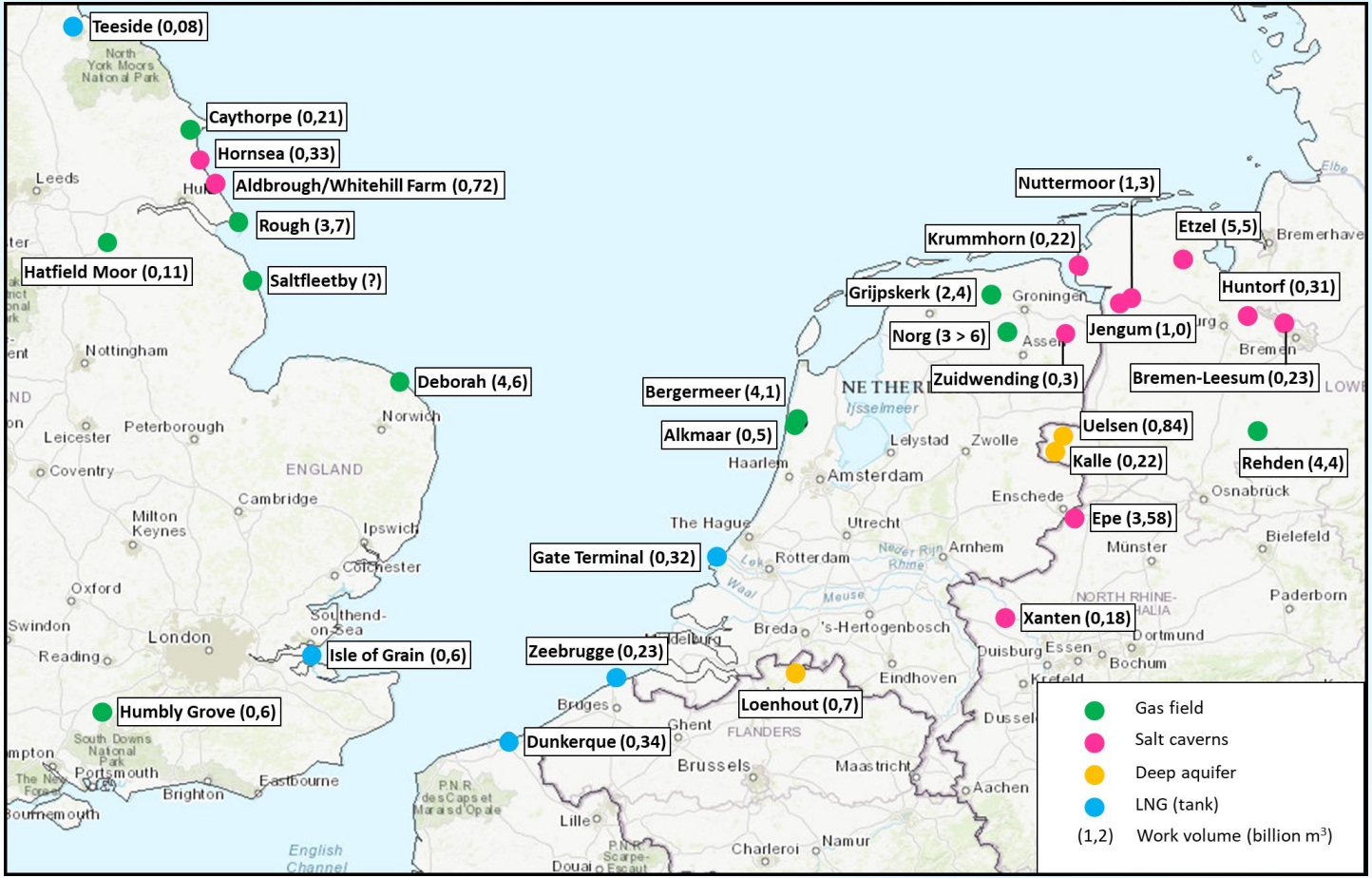
- Reduced diversity of primary energy supply with ongoing electrification (solar / wind)
- Energy consumption historically related to growth of subsurface (fossil) resources >> reduction and transformation
- Increased import dependence (gas production decline <> coal/nuclear decommissioning <> renewable development)
- Diversity of electricity generation: increasing share of intermittent production (solar / wind) at the expense of base load
- Energy storage: natural gas storage dominates, future needs for g-h-e balancing (delivery) and security of supply
- Preparedness to infrastructure failure: growing dependence E-net (electrification) vs decentralization of production

Subsurface contributions to energy transition

Technology	Low temp	High temp	Power	Transport	Feedstock
Geothermal Diversity Import dependency	Base load CO2 reduction	Base load CO2 reduction	Base load CO2 reduction		
Hydrocarbons E&P Security Diversity Import dependency	Base / peak load (winter)	Base load (bridge fuel)	Peak demand	CH4 >> H2	Base load (CH4 >> H2)
CC(U)S Environmental sustainability		CO2 reduction	CO2 reduction		Utilization and storage
Energy Storage Security Deliverability Preparedness	Green gas (winter) Hydrogen Heat (and cold)	Green gas (peak) Hydrogen	Green gas (peak) Compressed air Hydrogen (renew.) Pumped Accum.	Hydrogen	Peak demand (industrial gases)

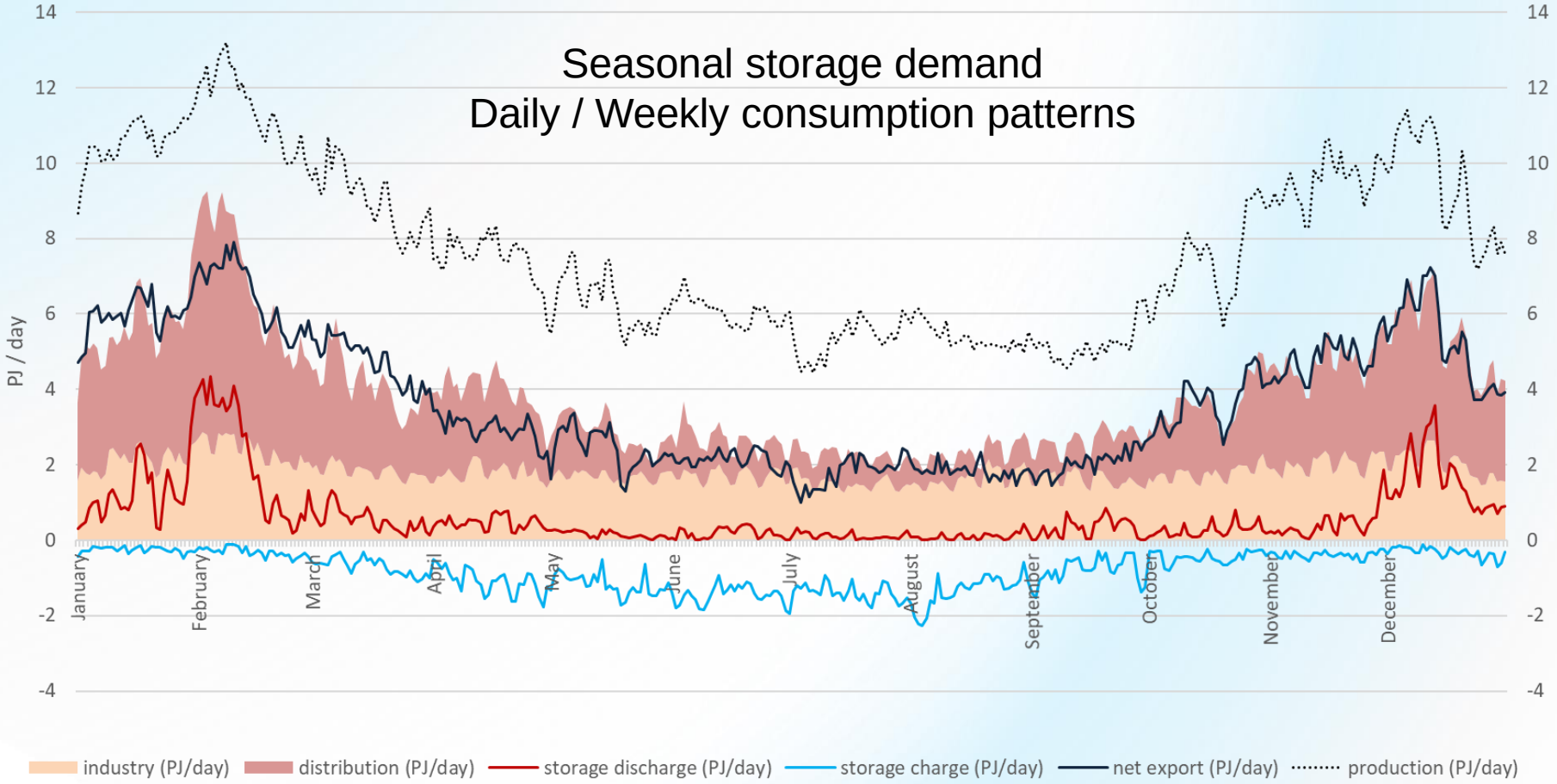
Natural Gas Storages, NL & Neighbours

(TNO/EBN 2018, ESTMAP 2016, GIE 2015)



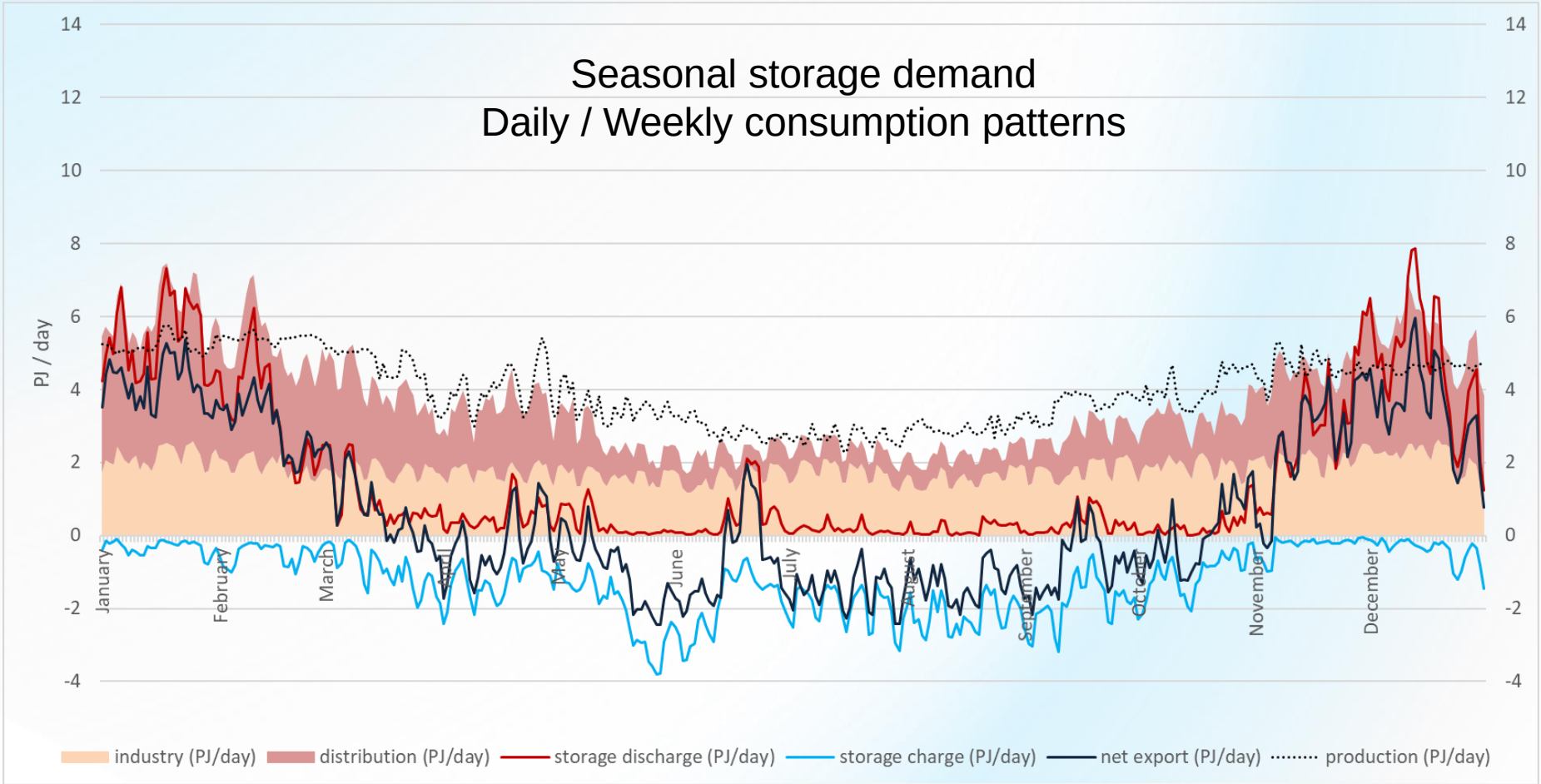
Dutch Gas Balance 2012

(based on GasUnie, 2013 report)



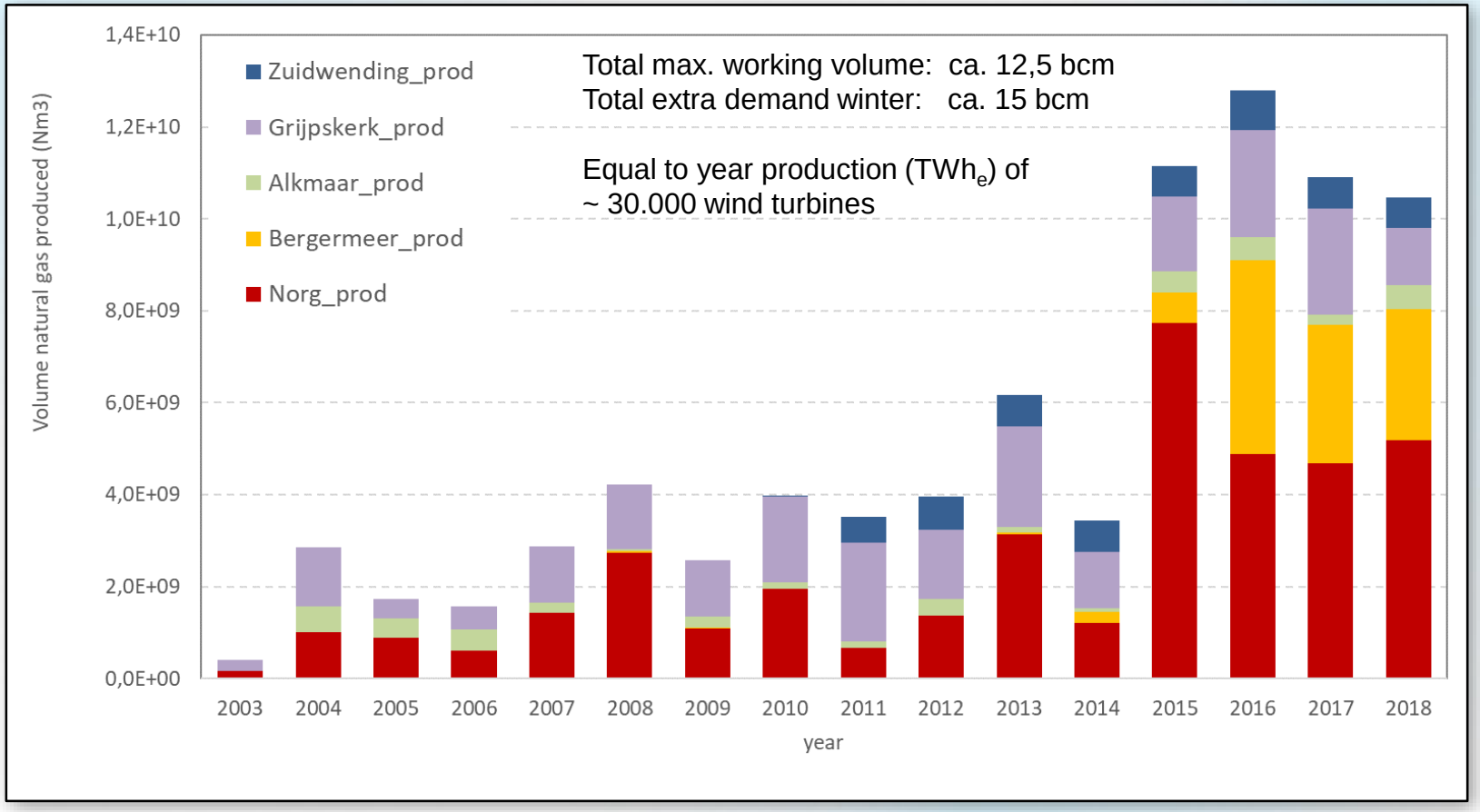
Dutch Gas Balance 2017

(based on GasUnie, 2018 report)



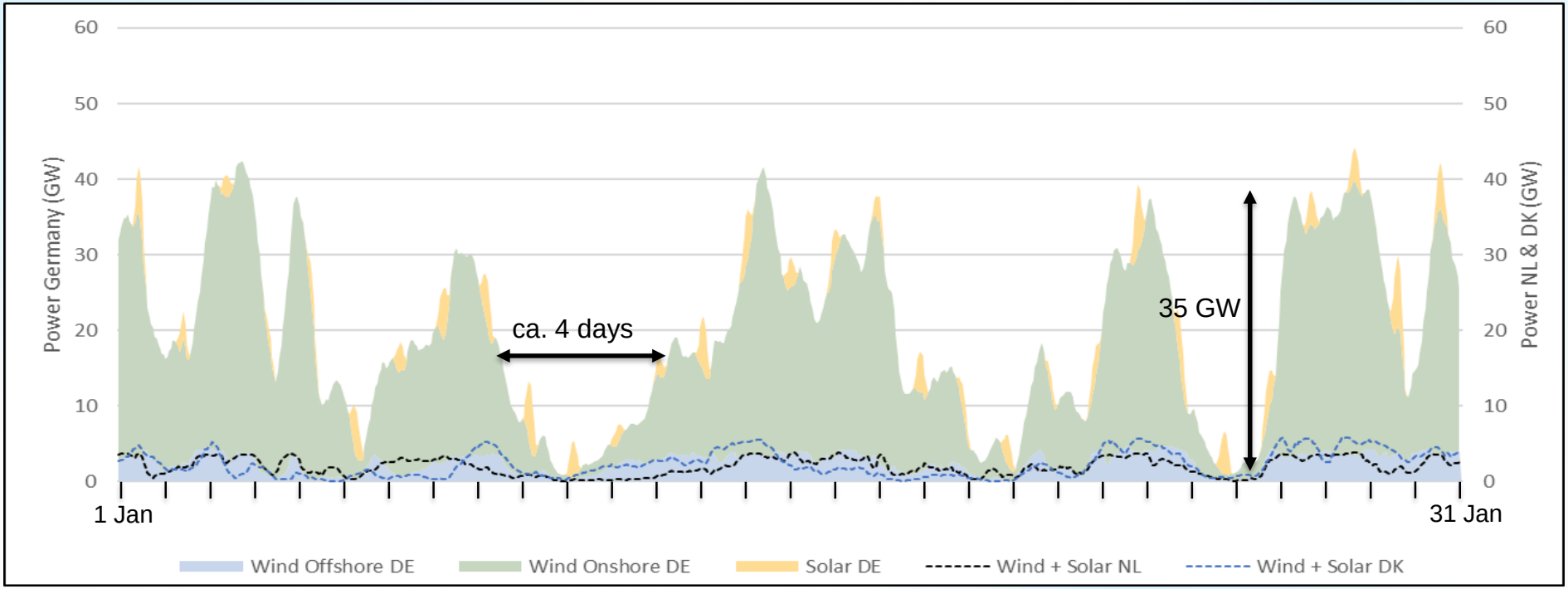
Yearly discharge from gas storages, Netherlands

(TNO, 2019)



Wind and Solar production, DE-NL-DK, January 2018

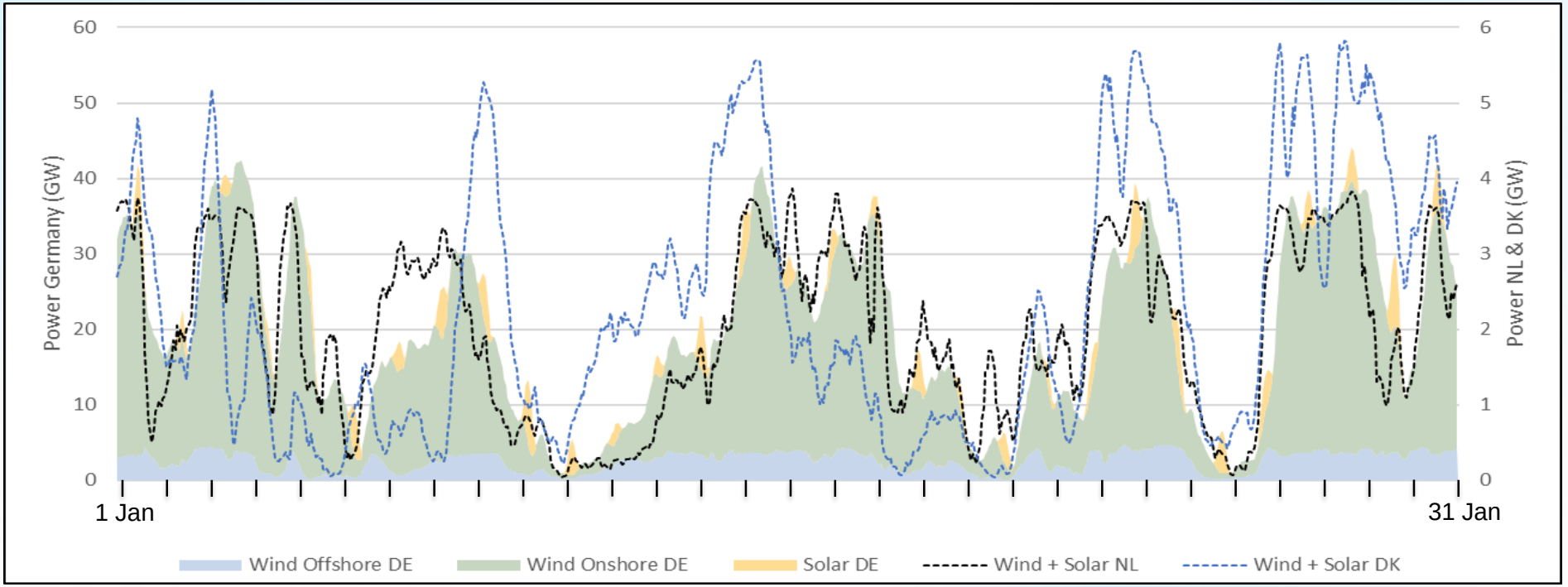
(Energy-charts.de, Frauenhofer 2019, ENTSOE, www.energidataservice.dk)



Germany: ca. 60 GW installed capacity (comparable to Dutch renewable ambitions in 2050)
ca. 30.000 wind turbines

Wind and Solar production, DE-NL-DK, January 2018

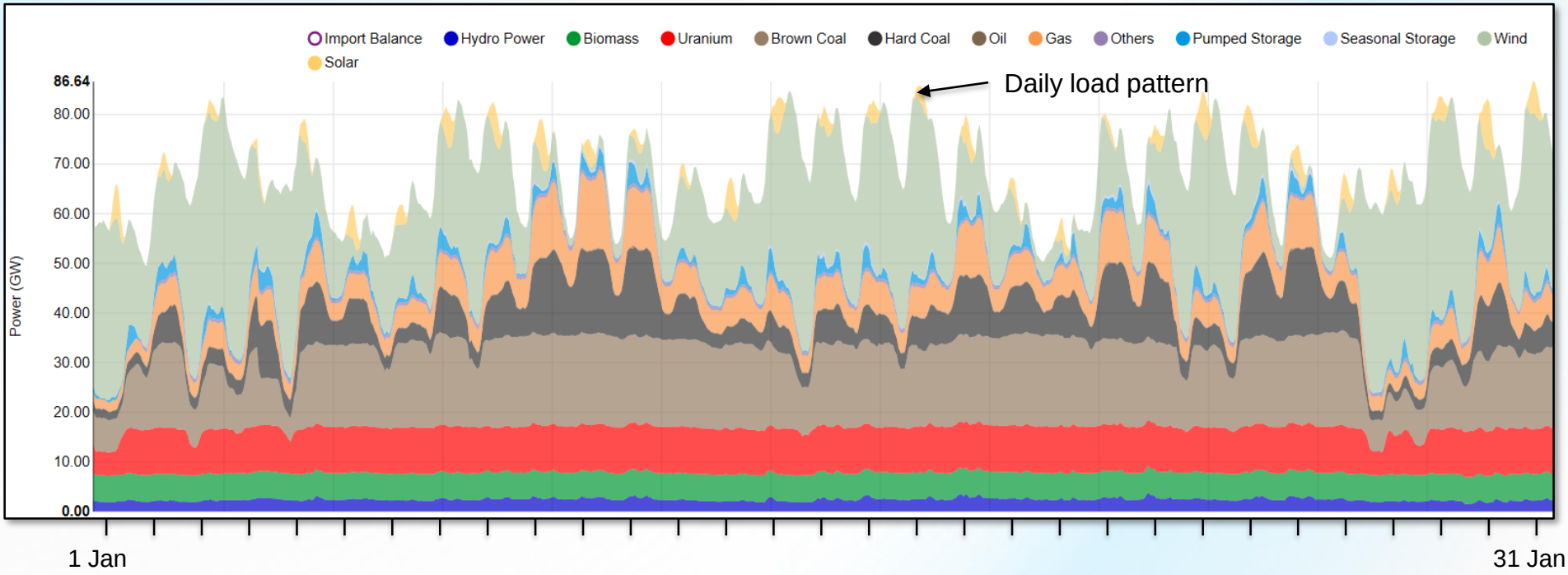
(Energy-charts.de, Frauenhofer 2019, ENTSOE, www.energidataservice.dk)



Similarity of wind patterns (NL and DK scaled to German wind capacity)

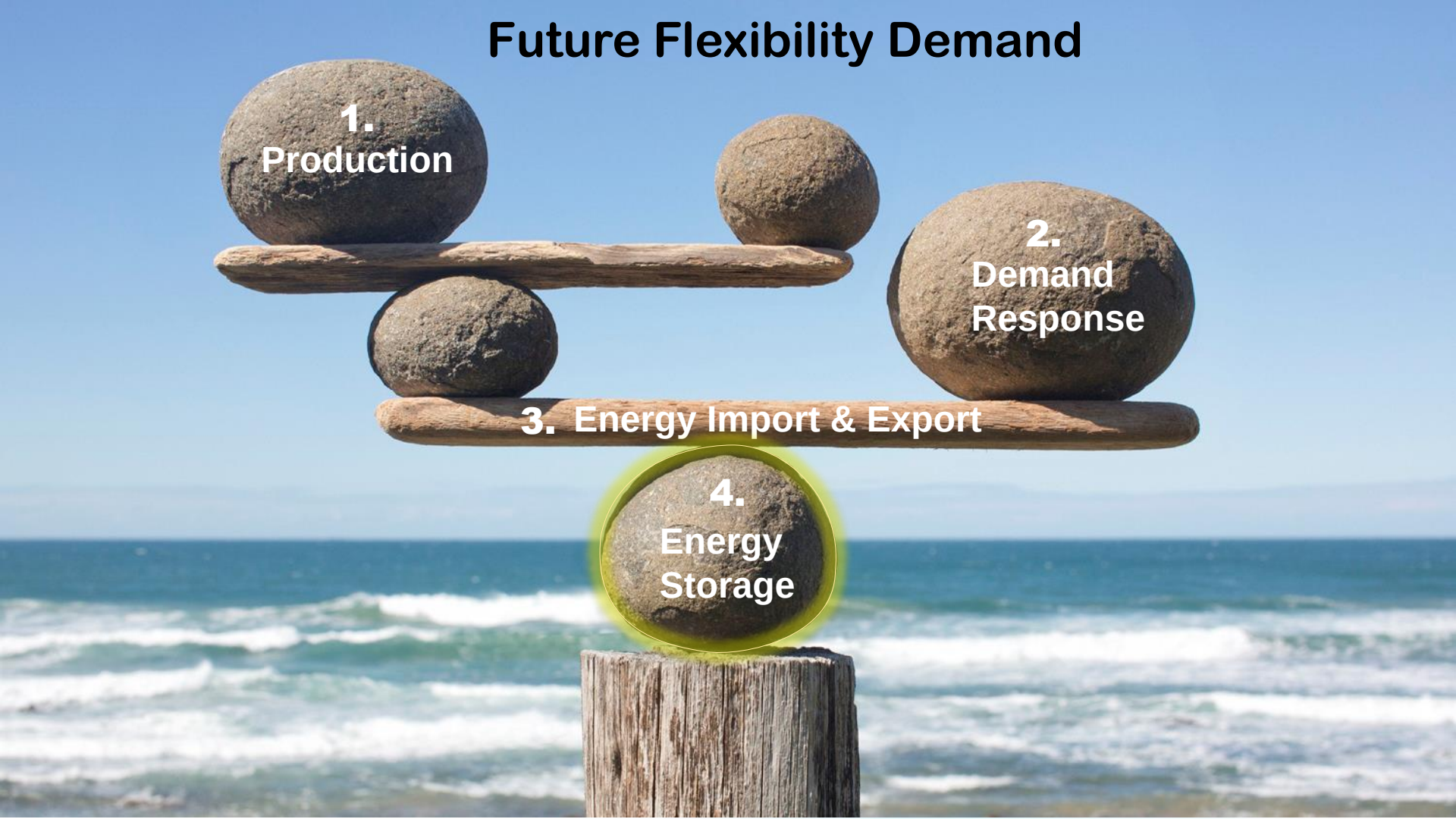
Electricity production Germany, January 2018

(Energy-charts.de , Frauenhofer, 2019)



Coal, Lignite and Natural gas mainly used as balancing capacity.

Future Flexibility Demand



Battery Storage

Jardelund (Northern Germany)
ca. 50 MW, duration 1 hour = 50 MWh

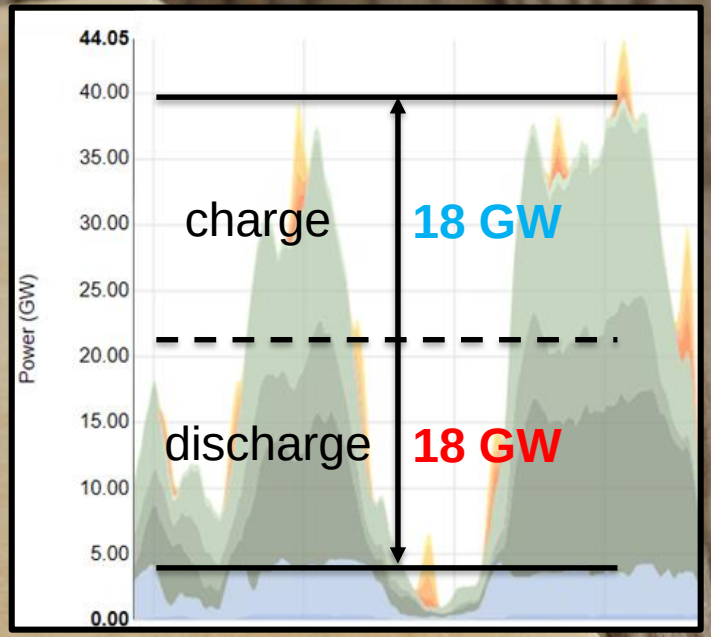
news.enecogroup.com

Storing one day of wind (18 GW)

18 GW x 24 hours = 432 GWh

Largest battery in EU = 50 MWh

$$\frac{432.000\ \text{MWh}}{50\ \text{MWh}} = 8640\ \text{batteries}$$



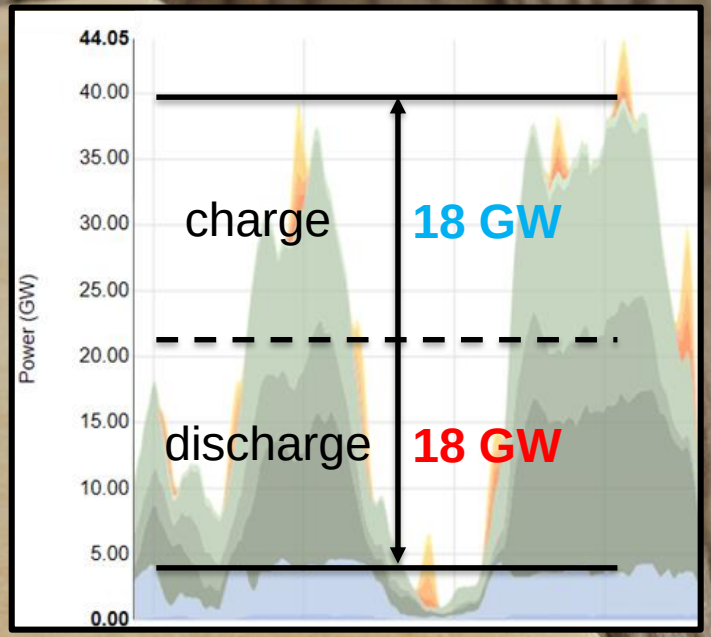
Natural batteries: Pumped Hydro Lakes

Storing one day of wind (18 GW)

18 GW x 24 hours = 432 GWh

Goldisthal = 8.480 MWh

$$\frac{432.000\ \text{MWh}}{8.480\ \text{MWh}} = 52\ \text{lakes}$$



Ca 167 pumped hydro lakes in Europe

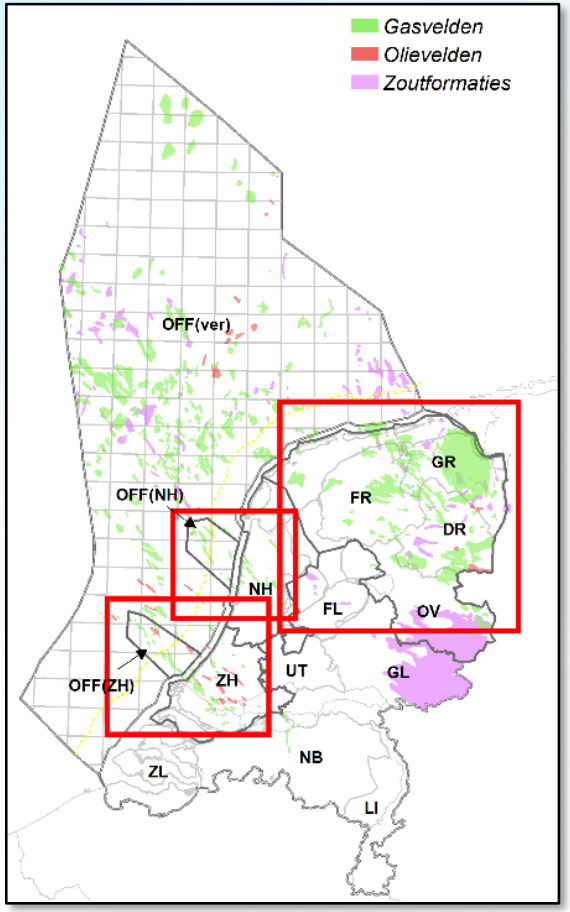
combined power 60 GW
average duration 10-12 uur
Total energy capacity ~0,6 TWh(e)

Norg gas storage (5 bcm work vol)

power 28 GW(th) → 14 GW(e)
duration 75 – 90 days
Capacity 49 TWh(th) / 24 TWh(e)
Hydrogen eq. ca. 8 TWh(e)

Hydrogen storage in gas fields

(TNO / EBN 2018, "Ondergrondse opslag in Nederland: Technische verkenning")



Estimated hydrogen storage demand NL 2050:
1 – 7,5 bcm H2 and 1 – 7,5 bcm green gas

- Seasonal demand (normal and extreme cold winters)
- Daily - weekly fluctuation wind/solar production
- Energy conversions (CH4 > H2, power to gas, gas to power)

Estimated effective working volume in 10 salt pillars (caverns)

- Developed pillars: ca. 4 bcm (70 caverns)
- Undeveloped pillars: ca. 13 bcm (250 caverns)
- **Proven technology (US / UK)**

Estimated effective working volume 86 gas fields

- Onshore / near shore: ca. 127 bcm
- **Technology / feasibility under investigation**

Will geology catalyse the energy transition?

- **Past energy transitions defined by subsurface primary resources, accumulative**

- **Next transition will be transformational (from subsurface resource to renewables)**

- **Important challenges demanding large energy volumes and rates:**
  Security of supply: (import dependency, seasonal consumption patterns)
  Resilience / Deliverability: (peak demand, solar/wind intermittency, energy diversity)
  Environ. sustainability: (CO_2 reduction)

- **Subsurface role during/after energy transition:**
  Resource supplier: (geothermal base load heat, natural gas as bridge fuel)
  System service for supply and delivery: (energy storage G-H-E)
  CO_2 reduction: (CCS)

Will Geology catalyze Europe's next Energy Transition?

Thank you for your attention

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