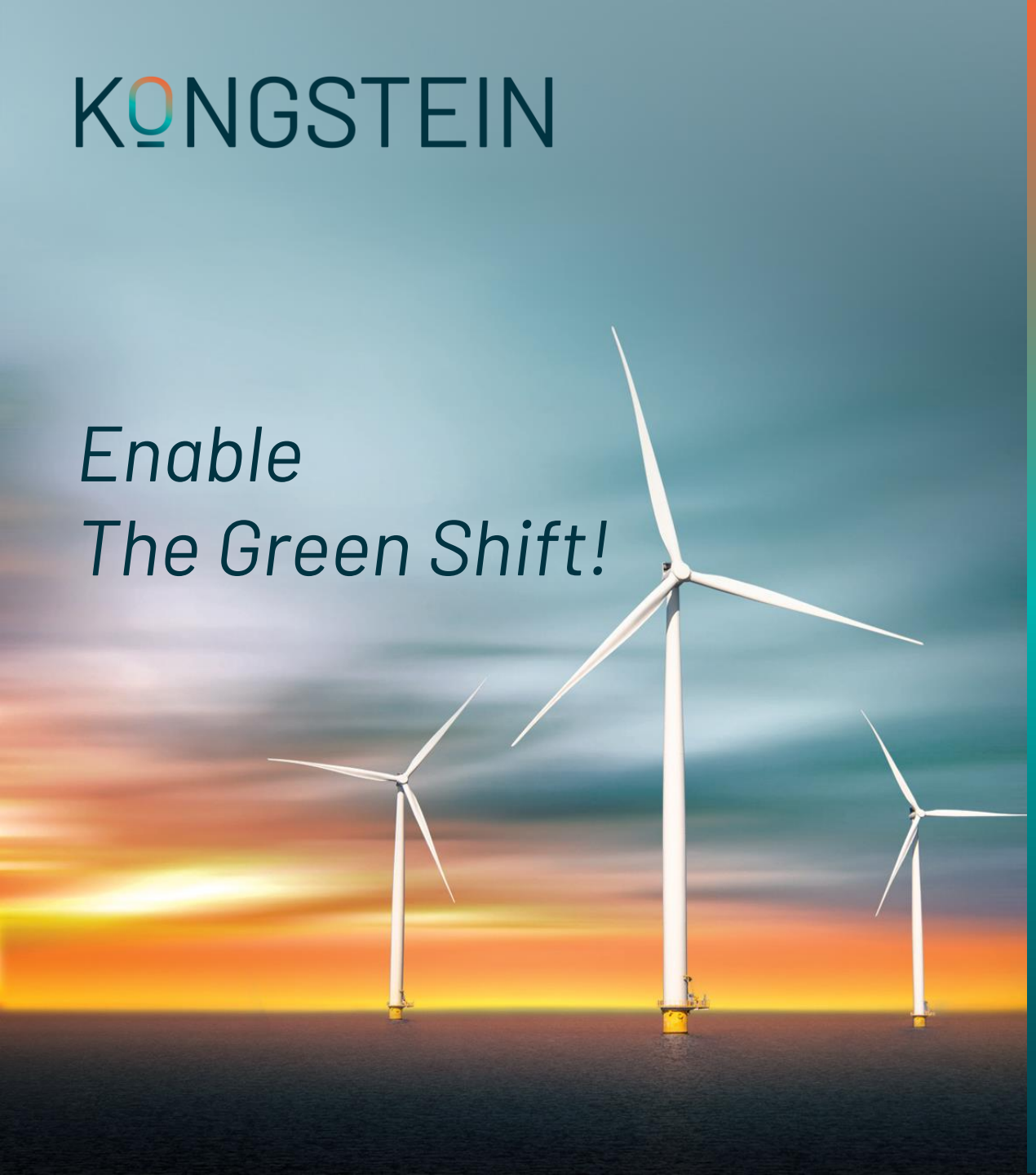
KONGSTEIN

Enable
The Green Shift!



ALTERNATIVE OFF TAKERS FOR EXCESS ENERGY FROM HVDC IMPORT

Or: what to do with curtailed energy apart from producing hydrogen?

Holger Krause, Lotte Spaargaren, Michael Ring

Braunschweig, 21.09.2023

AGENDA

01 About KONGSTEIN

02 Curtailment

03 Possible technologies to use curtailed energy

04 Conclusion

ABOUT KONGSTEIN

We are dedicated to accelerating the green shift!

We provide with the right technical advice for your commercial success in the offshore wind, green hydrogen, and maritime industries.

WHAT IS OUR EXPERTISE?

We advise and support our clients in:

- OFFSHORE WIND
- MARITIME
- OFFSHORE GRID
- GREEN HYDROGEN

HOW DO WE ACCELERATE THE GREEN SHIFT?

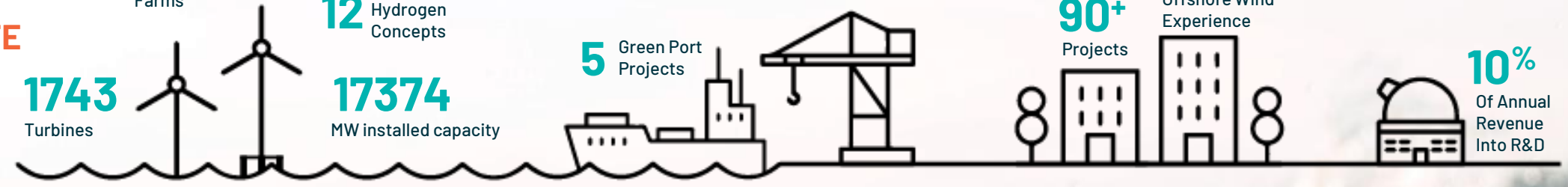
37 Offshore Wind Farms

12 Floating Offshore Wind projects

12 Green Hydrogen Concepts

1743 Turbines

17374 MW installed capacity



5 Green Port Projects

90+ Projects

100+ Accumulated Offshore Wind Experience

10% Of Annual Revenue Into R&D

We advise you throughout the value chain

From early-stage developments to decommissioning.

MARKET AND OPERATIONS INSIGHTS

- Tailor-Made Market Studies
- Market Entry Strategies
- Supply Chain Reports

TECHNICAL CONCEPTS AND ANALYSIS

- T&I Concepts
- H2 Logistics Concepts
- CO2 Footprint analysis
- Vessel Design Review
- Decommissioning Concepts

PROJECT MANAGEMENT

- Tender and Bid Support
- T&I Package Mgmt.
- WTG Package Mgmt.
- Cable Package Mgmt.

ASSET AND RISK MANAGEMENT

- O&M Strategy and Concepts
- OPEX Modelling
- Risk Quantification

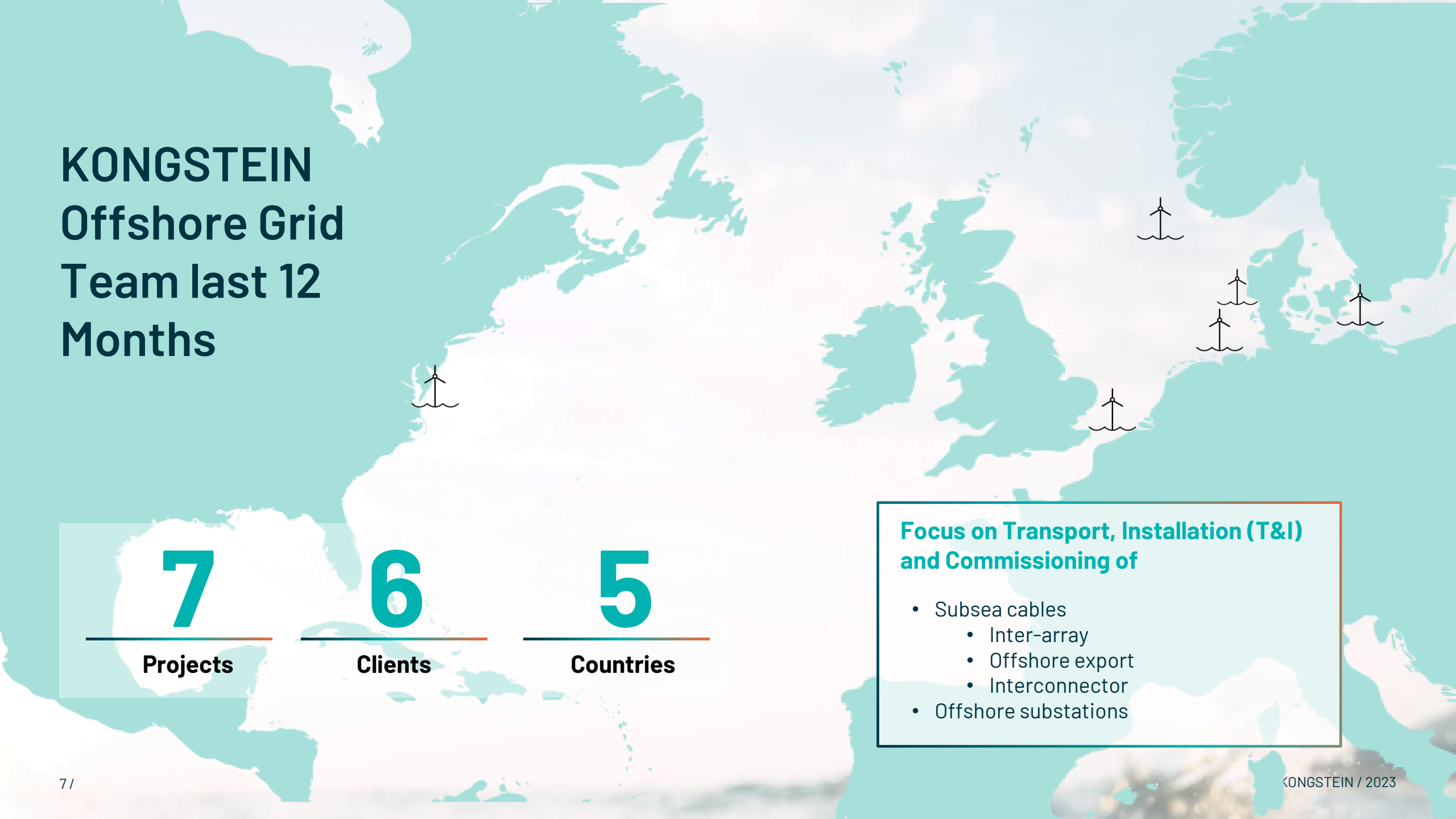
Few facts about KONGSTEIN

7
OFFICES

10
NATIONALITIES

1
GOAL

KONGSTEIN Offshore Grid Team last 12 Months



7
Projects

6
Clients

5
Countries

Focus on Transport, Installation (T&I) and Commissioning of

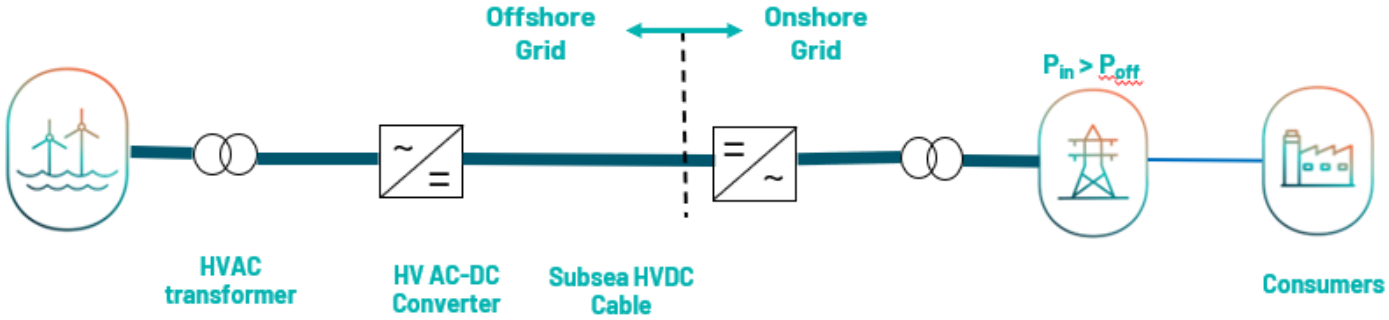
- Subsea cables
  - Inter-array
  - Offshore export
  - Interconnector
- Offshore substations

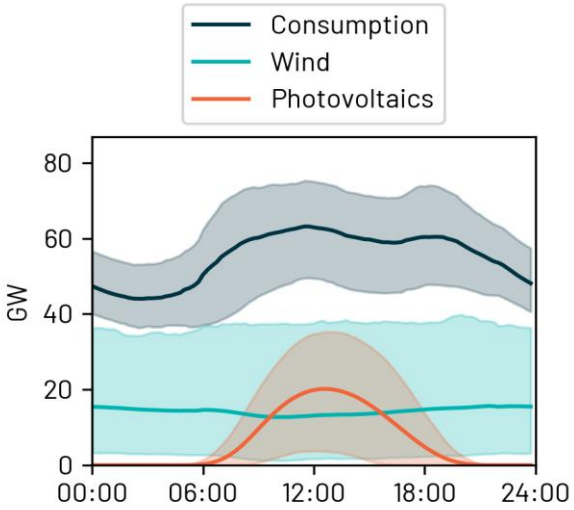
CURTAILMENT

What is curtailment?

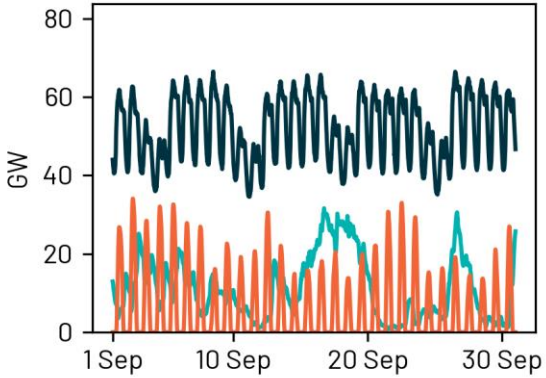
Curtailment means instructing power plant operators to reduce power output to avoid grid instability

- Onshore grid not (yet) set-up to meet dynamics of renewable energy production
- Demand and supply (by RE) follow different cycles

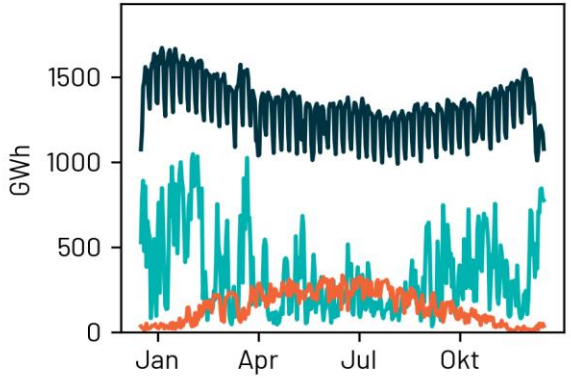




Averaged daily profile over 2022 of electricity consumption and production of solar and wind



Electricity consumption and production of solar and wind for Germany in September 2022



Daily electric energy consumption and production of solar and wind for Germany in 2022

Source: Bundesnetzagentur SMARD, www.smard.de

Is Curtailment an issue, and if yes, how big?

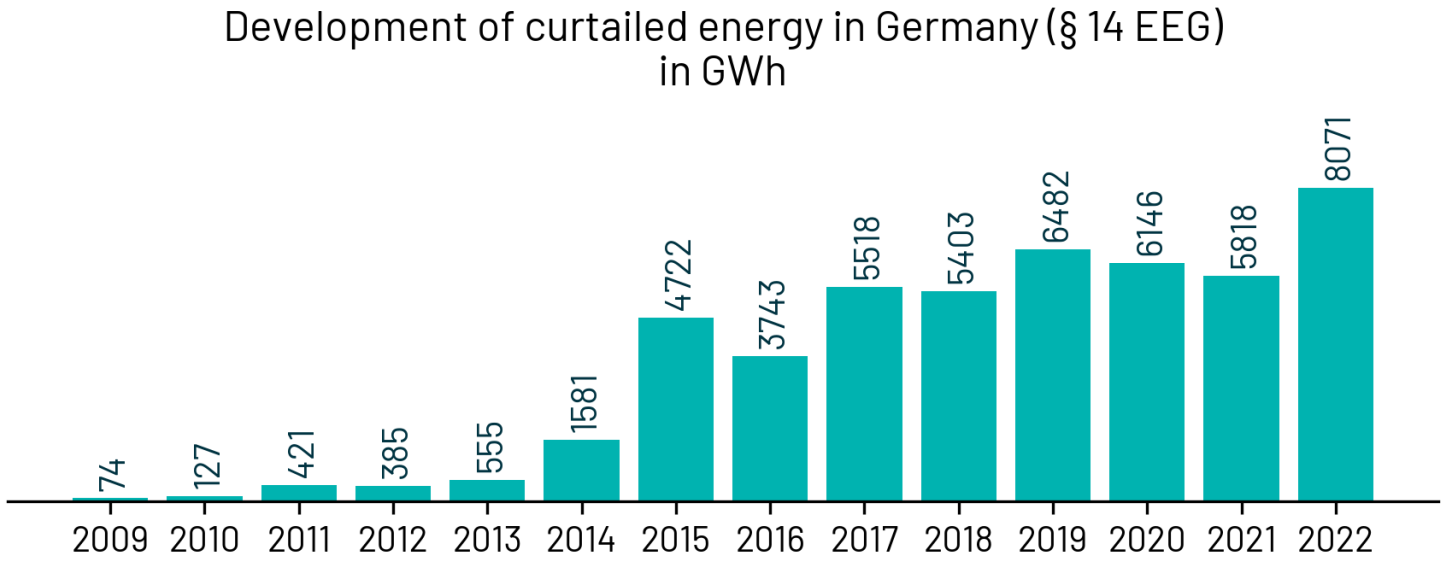
Curtailment means instructing power plant operators to reduce power output to avoid grid instability

- >3% of German renewable energy production of 2022 is curtailed (>1% of total produced electricity)
- Ca. > 95% curtailment on windpower (on- and offshore)
- TSOs compensate plant operators (i.e. 800 Mio in 2021)
- **Curtailment is in essence waste**

Münchner Merkur, Dez. 2022

Focus online, Feb. 2023

FAZ, Sept. 2023



Source: www.bundesnetzagentur.de

Why is 3% waste a problem?

How much is 8.071 GWh?

100x charge of all EV in Germany (drive each 30.000km)

Yearly output of:
- 338 offshore wind turbines (22% of German total) or
- 1.614 onshore wind turbines (5,7% of German total)

Global Perspective

- 8.000.000.000 people on the planet
- Everyone has the same right on same living standards
- No one is willing to reduce lifestyle

vs

- Limited resources
- Climate change

Regional Perspective

- Waste of resources
  - Supply chain
  - Permit and engineering
  - Courts
- Reduced acceptance if turbines don't turn

Individual Perspective

- Consumers pay for the grid
- And Consumers still pay for curtailment

*
- *1.17Mio EV total, (www.statista.com) avg. Battery cap. 68,7 kWh / 300km range (capacity from www.ev-database.com)*
- *Offshore wind: avg. Turbine rating 5,3MW, full-load hours 4.500h, total 1.563 WTG in German waters (based on numbers from Deutsche Windguard)*
- *Onshore wind: avg. 2MW, 2.500h, 28.517 WTG total (based on numbers from Deutsche Windguard)*

Curtailment in the future?

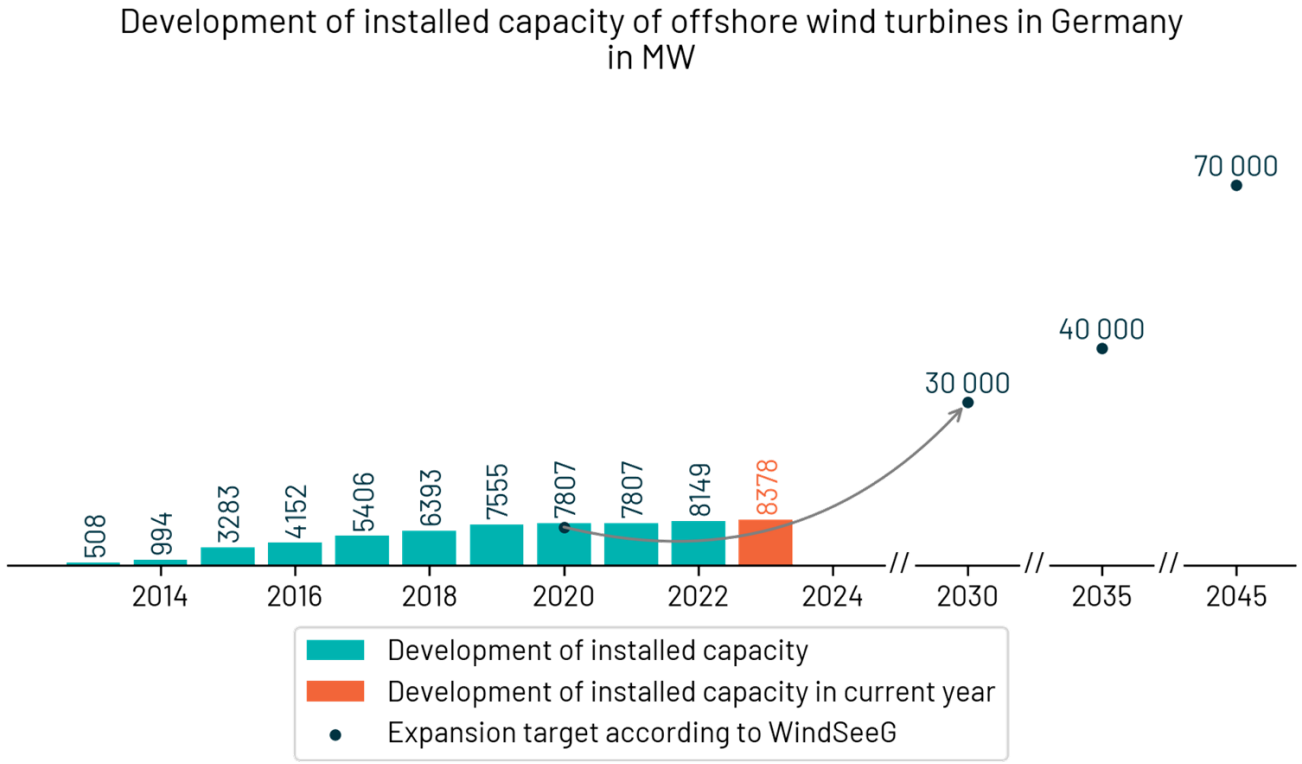
Attempt on a prognosis

- Influx of offshore wind power to increase from 8,4GW (2023) to 70 GW (2045)
- Planning and execution of onshore grid needs to consider a higher stakeholder complexity than offshore wind, p.e. additional
    - Landowners
    - Multiple Federal states
    - Municipalities

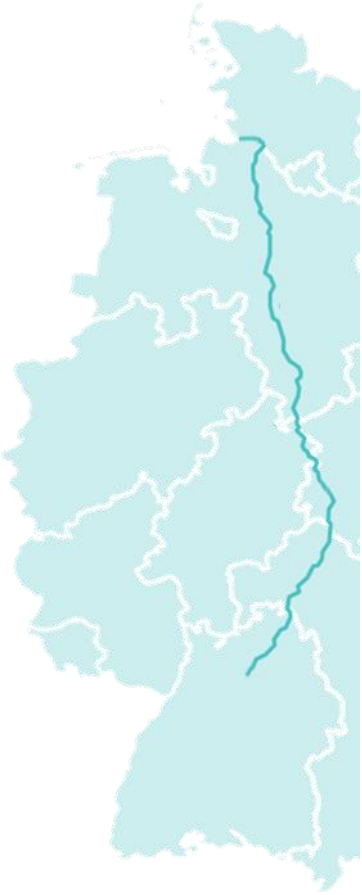
    ->i.e. SuedLink: 700km, 15 segments,

    6 federal states, thousands of stakeholders ...

➔ *Higher likelihood for delays on onshore grid*
➔ *High likelihood for an increase in curtailment*
➔ *Large potential for alternative offtakers*



Source: www.bundesnetzagentur.de

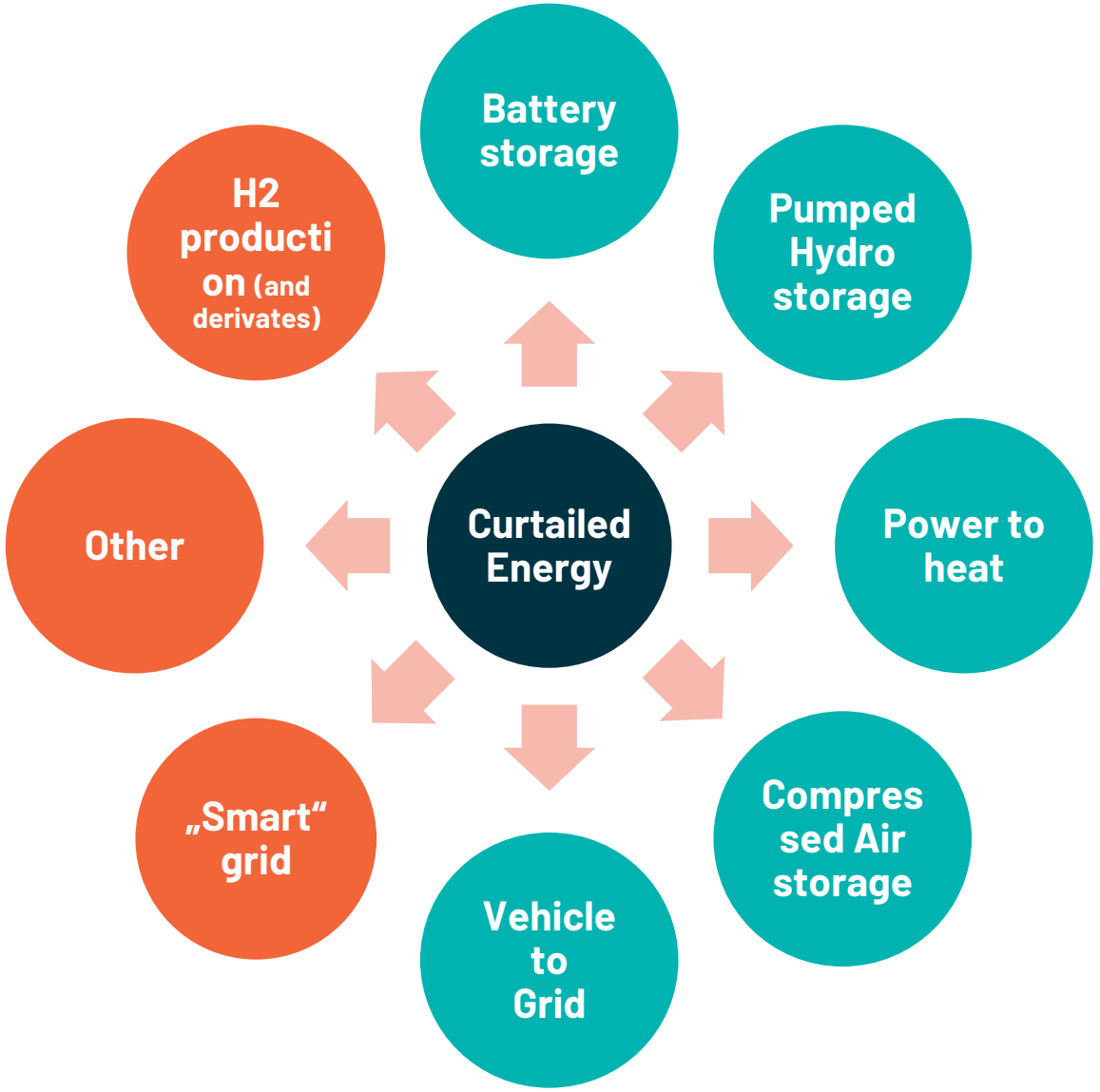


TECHNO-LOGIES TO USE CURTAILED ENERGY

Potential technologies

How to make use of curtailed energy if the grid can't be expanded fast enough?

- *Variety of options*
- *Different maturity levels*
- *Different capacities*



Electrochemical Battery Storage

Fairly mature technology, can be implemented locally / decentralized.

German total capacity:
9.4 GWh | 6.1 GW
(1.3 GWh | 1.1 GW from large-scale storage)

Largest project in Germany
79 MWh | 72 MW (RWE, Werne, NRW)

Largest project in the world:
1600 MWh | 400 MW (Moss Landing Energy Storage Facility, CA, USA)

Sources:
www.bundesnetzagentur.de
www.nsenergybusiness.com/projects/moss-landing/

Map created with google.com/maps

Projects > 1MWh capacity

Readiness level

- Large scale projects realized / possible
- Mature technology
- Pilot projects

Pumped Hydro Energy Storage

Very mature technology (99% of all storage capacity worldwide).
Feasibility dependent on local geography

German total capacity:
37.4 GWh | 6.3 GW

Largest project in Germany
9.6 GWh | 1.06 GW, Pumpspeicherwerk Goldisthal

Largest project in the world:
40 GWh | 3.6 GW, Fengning Pumped Storage Power Station, China

Map created with google.com/maps

Readiness level

- Large scale projects realized / possible
- Mature technology
- Pilot projects

Sources (combined):
- *Prospects for pumped-hydro storage in Germany, Bjarne Steffen*
- *www.bundesnetzagentur.de*

Power to Heat

Suitable technology to couple with district heating. Ideal for densily populated areas. Ideally connected to heat storage.

German total capacity:
4.6 GWh Heat Storage | 890 MW PtH

Largest project in Germany (commissioning 2023)
2.6 GWh Heat Storage | 120 MW PtH*, Vattenfall
Reuter West, Berlin

World wide, large-scale heat storage:
Ouarzazate Solar Power Station, Morocco

* Thermal heat provided by electricity along with 3 gas powered boilers.

Map created with google.com/maps

Projects acc. power rating, not capacity

Readiness level

- Large scale projects realized / possible
- Mature technology
- Pilot projects

Sources (combined):
- Drucksache 19/30317 – Antwort der Bundesregierung zu Kleiner Anfrage... „Situation der Energiespeicher in Deutschland"
- https://de.wikipedia.org/wiki/Power-to-Heat
- www.reuters.com/article/vattenfall-heat-berlin-idINL8N1IY3TL
- https://group.vattenfall.com/press-and-media/newsroom/2022/germanys-largest-heat-storage-in-the-starting-blocks

Compressed Air Energy Storage

Potential dependent on suitable storage medium (i.e. local geophysical conditions)

German total capacity:
321 MW | 1200 MWh

Largest project in Germany:
321 MW | 1200 MWh, planned to upgrade to 1680MWh (Huntorf)

Largest project in the world:
110 MW | 2860 MWh (McIntosh CAES Plant, USA)

Map created with google.com/maps

Readiness level

- Large scale projects realized / possible
- Mature technology
- Pilot projects

Sources (combined):
- Bundesnetzagentur and Marktstammregister
- Raju, Mandhapati, and Siddhartha Kumar Khaitan. "Modeling and simulation of compressed air storage in caverns: a case study of the Huntorf plant." Applied energy 89.1 (2012): 474-481.

Vehicle to Grid

High potential technology.
Depends on widespread use of EV with bi-directional charging capability and „smart“ grid.

Capacity per vehicle:
Car 30-100 kWh, Truck 0.5 – 1 MWh, Ferry 4.3 MWh

German total capacity:
Potential in Germany, if all cars are EV -> 3.3 TWh

Largest project in Germany commissioning 2023
1.5 MWh | 45 cars

Largest project in the world:
24 MWh | 700 cars

Map created with google.com/maps

Readiness level

- Large scale projects realized / possible
- Mature technology
- Pilot projects

Sources (combined):
- NetzeBW, NETZlabor E-Mobility-Carré, accessed on 2023-09-20 (https://www.netze-bw.de/unsernetz/netzinnovationen/netzintegration-elektromobilitaet/e-mobility-carre)
- E-drivers.com, 2021, Netze BW lanceert laatste twee "smart home charging" gridlabs, accessed on 2023-09-20 (https://e-drivers.com/netze-bw-lanceert-laatste-twee-smart-home-charging-gridlabs/)
- Smart Energy International, 12020, World's biggest of ist kind vehicle-to-grid pilot launches, accessed on 2023-09-20 (https://www.smart-energy.com/regional-news/europe-uk/worlds-biggest-of-its-kind-vehicle-to-grid-pilot-launches/)

Summary

	Total Capacity Germany in GWh	% of 8.071 GWh (load cycles to 100%)	Technology Readiness	Mature Technology?
Battery Storage	9.4	0.12% (859)	Large scale implemented	Flexible and scalable. Resource intense
Pumped Hydro	37.4	0.46% (216)	Large scale implemented	Mature, but limited locations
Power to Heat	4.6	0.06% (1.754)	Large scale implemented	Mature and ideal to couple with district heating
Compressed Air	1.2	0.015% (6.725)	Large scale implemented	Very limited locations
Vehicle 2 Grid	0.002	0.000025% (4035500)	Pilot phase	Bi-directional charging required + "smart" grid

CONCLUSION

Key Takeaways

- Curtailment, although “just” 3%, should not be neglected.
- Curtailment will likely increase d/t mismatch between growth in renewable power plants vs. expansion of grid infrastructure.
- Various technologies are available beside from H2 production to use curtailed energy but still have potential to be more widely applied.

Thank you for your time.

Your contact people at KONGSTEIN

We are always happy to support you with any question

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