Integrated grid projects and offshore wind

A TSO perspective

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Agenda

1. Renewables development in the 50Hertz control area
2. New 50Hertz offshore interconnectors
3. Drivers for interconnectors
4. Challenges for combining offshore wind conections with interconnectors

Renewables development in the 50Hertz control area

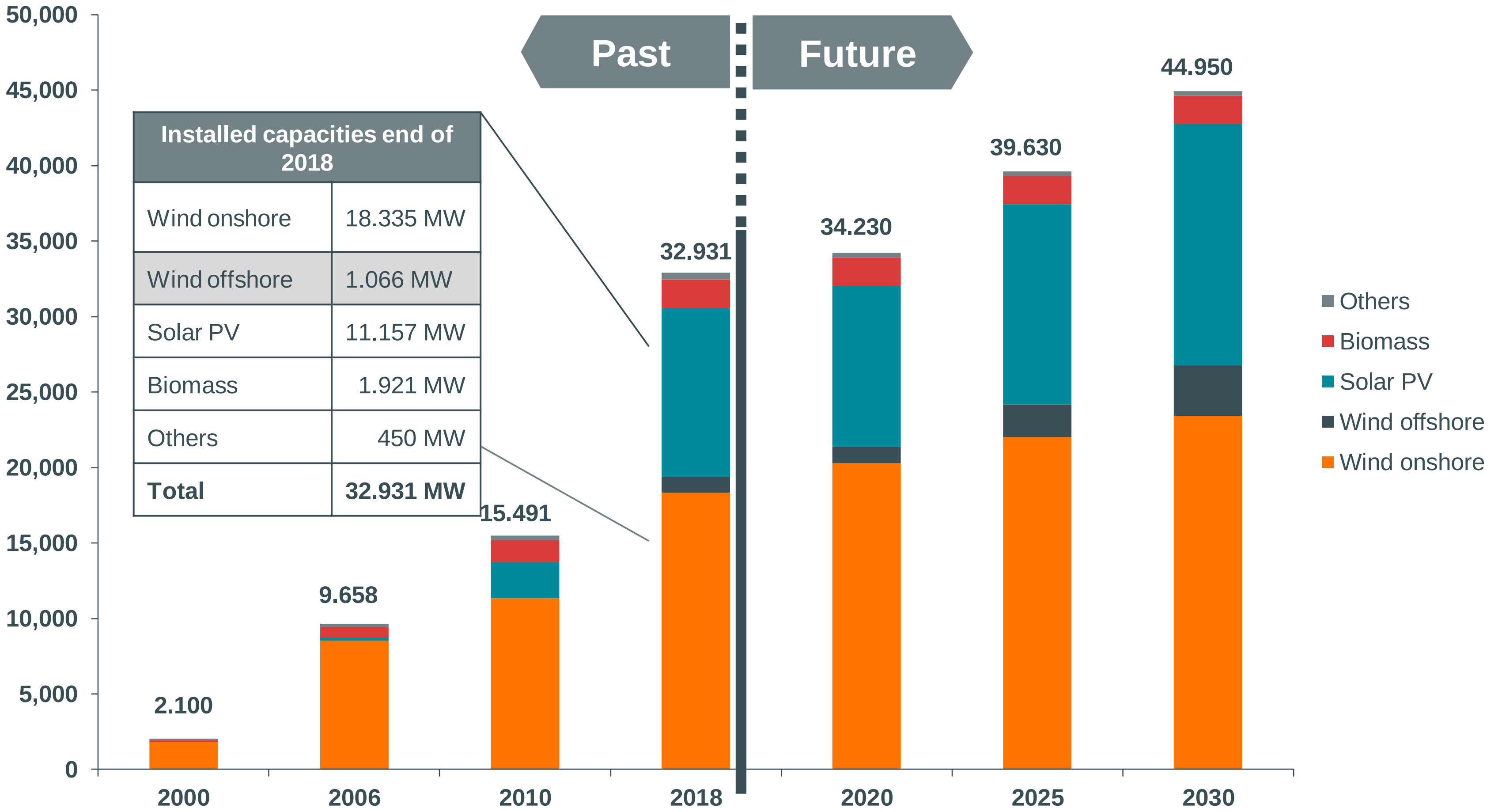
50Hertz at a glance

	2010 (share Germany)	2017/18 (share Germany)
Grid area	109,589 km^2 (~31%)	109,619 km^2(~31%)[1]
Length of lines	9,800 km (~30 %)	10,200 km (~30 %)[1]
Max. load	~ 17 GW (~20 %)	~ 16 GW (~20 %)[1]
Power consumption (based on electricity supplied to end-consumers in acc. with Renewables Energy Law „EEG")	~ 98 TWh (~20 %)	~ 96 TWh (~20 %)*
Installed capacities - of which Renewables - of which Wind	38,354 MW (~35%) 15,491 MW (~30%) 11,318 MW (~40%)	54,069 MW (~26%)[1] 32,352 MW (~29%)* 19,414 MW (~35%)*
RES share in power consumption	~ 25 %	~ 55.0 %*
Turnover - of which Grid	5.6 bn. € 0.6 bn. €	9.9 bn. €[1] 1.3 bn. €[1]
Employees	643	1,043[1]

Source: 50Hertz; [1]as of 31/12/2017; *preliminary data; as of 08/01/2019

RES capacities in the 50Hertz grid area grow significantly

Installed capacities in MW

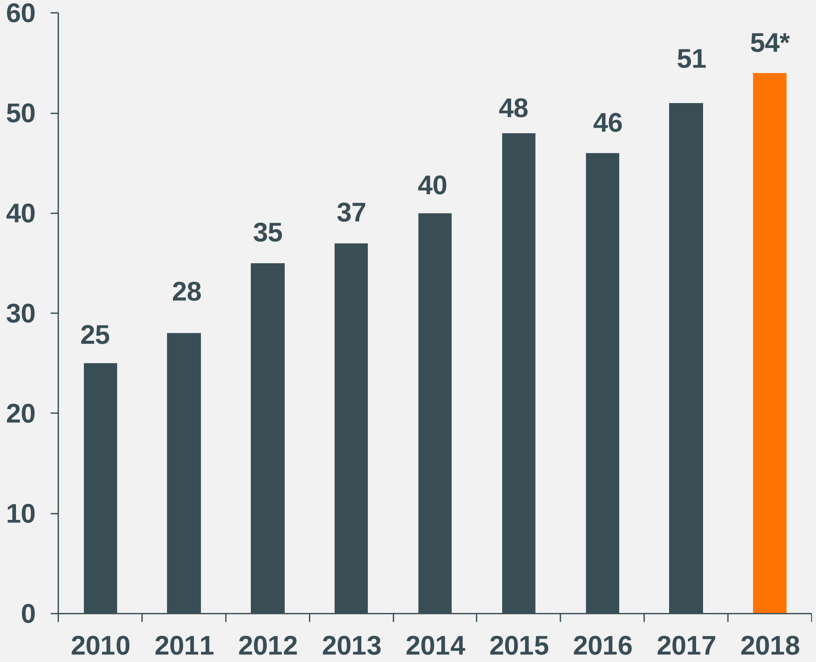


Installed capacities end of 2018	
Wind onshore	18.335 MW
Wind offshore	1.066 MW
Solar PV	11.157 MW
Biomass	1.921 MW
Others	450 MW
Total	**32.931 MW**

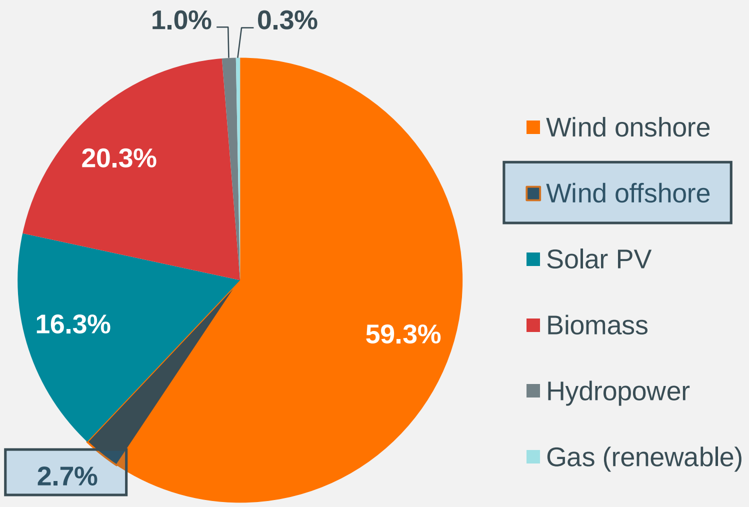
Source: 50Hertz; *preliminary data; as of 08/01/2019

Offshore wind provides reliable and stable electricity generation despite a limited share in renewables generation

50Hertz grid area: development of RES feed-in (TWh)



50Hertz grid area: composition of RES feed-in (2018, in %)



Expected to rise due to recent connection of >700 MW new wind parks

Source: 50Hertz; *as of 08/01/2019

Offshore wind contributes to the ambitious goals in renewable generation of Germany and Europe

	EU targets	German targets	
CO_2 emission reduction[1]	**2030:** 40%	**2020:** 40% **2030:** 55% **2050:** 80-95%	**2017: 27.7%**
RES share in power consumption	**2030:** 27%	**2025:** 40-45% **2030:** 65% **2050:** 80%	**DE 2017: 36.2%** **50Hertz 2017: 53%**
Efficiency (reduction of power consumption[2]**)**	**2030:** 27%	**2020:** 20%	**2016: 6.3%**
Nuclear		phase-out until **2022**	**2018: 7 op.**

1 compared to 1990 levels (ratification of the Kyoto protocol)

2 compared to 2008 levels

Offshore projects in the Baltic Sea (I/II)

In Operation/ Test Operation

Under Construction

1 Kontek interconnector

Commissioning	1996

Baltic 1

2 Commissioning	2011
Capacity/Technology	48 MW – 150 kV AC

3 Baltic 2

Commissioning	2015
Capacity/Technology	288 MW – 150 kV AC

Cluster Baltic

4 Wikinger (Cluster Westlich Adlergrund, Ostwind 1)

Test Operation	12/2017
Capacity/Technology	350 MW – 220 kV AC

5 Arkona (Cluster Westlich Adlergrund, Ostwind 1)

Test Operation	09/2018
Capacity/Technology	385 MW – 220 kV AC

Cluster Ostwind 1

6 Kriegers Flak Combined Grid Solution (KF CGS)

Planned Commissioning	Q1/2019
Capacity/Technology	400 MW DC (VSC B2B Konverter) 150 kV AC (Cross Connection)

Offshore projects in the Baltic Sea (II/II)

Cluster Ostwind 2

7 **Arcadis Ost 1** (Cl. Westl. Adlergrund 2, Ostwind 2)

Planned Commissioning	2021/2022
Capacity/Technology	247 MW – 220 kV AC

8 **Baltic Eagle** (Cluster Westl. Adlergrund 2, Ostwind 2)

Planned Commissioning	2021/2022
Capacity/Technology	476 MW – 220 kV AC

9 **Offshore test site**

Possible Commissioning	
Planned Capacity/Technology	≈ 300 MW – 220 kV AC

10 **Hansa PowerBridge interconnector**

Planned Commissioning	2025/2026
Planned Capacity/Technology	≈ 700 MW – 300 kV DC

11 **OST-6-1**

Possible Commissioning	
Planned Capacity/Technology	3 x 300 MW – 220 kV AC

Under Construction

Planning/Permission

New 50Hertz offshore interconnectors

Combined Grid Solution – combination of wind parks and interconnector

- CGS will link the German Mecklenburg-Western Pomerania and the Danish region of Sjaelland
- Interconnection between the existing German offshore wind farms Baltic 1 & 2 and the Danish offshore wind farm (OWF) Kriegers Flak (under construction)
- Project partners: Energinet.dk (Denmark) and 50Hertz (Germany)
- The project is co-financed by the European Energy Program for Recovery (EU)

Project overview/ © 50Hertz

Hansa PowerBridge – point-to-point interconnector

- 700 MW interconnection between Sweden and Germany
- Cooperation Agreement signed January 2017
- Operational in 2025/26
- Taps into Scandinavian hydro storage potential while German volatile RES infeed grows rapidly

- Choice for DC point-to-point connection
  - Strategic importance for energy
  - Permament and reliable availability of trading capacity
  - No additional complexitiy from linkage with other grid projects
  - Experience from operation of CGS required
  - Necessary DC breakers not yet in use
  - Currently uncertainty about Swedish offshore wind policy

Drivers for interconnectors

Further increase of interconnector capacities is demanded on EU level

Drivers for additional interconnectors

$$EU - Ziel = \frac{interconnector\ capacity}{total\ installed\ generation\ oer\ country}$$

10% 2020 → **15%** 2030

integration of volatile RES in-feed in the grid

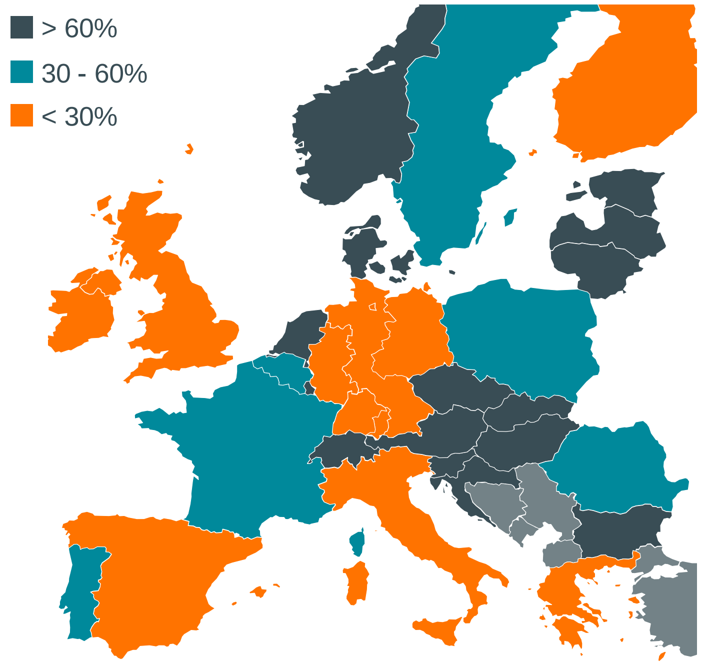
Tapping potential hydro storage capacities in Scandinavia

Enhanced security of supply

Completion of Internal Energy Market; balanced electricity prices

Interkonnektoren - Intensität ENTSO-E 2030

Interconnector capacity [GW] in relation to installed generation capacity of renewables [GW]

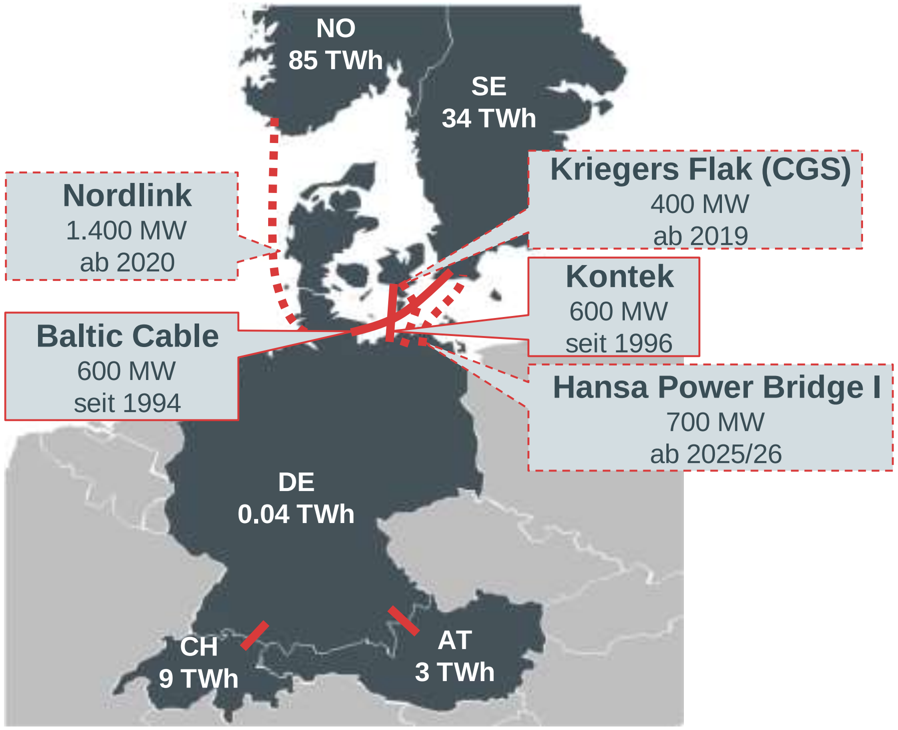


EU expert commmission relates need for interconnectors to electricity price spreads and defines a 30 % goal in relation to peak load and RES for 2030. This results in additional interconnection needs for Germany.

Quelle: TYNDP 2016 Vision 3; EU-Expertenkommission für Interkonnektoren (2017)

New interconnectors tap huge Scandinavian storage capacities

Interconnections to storage centres



Eigenschaften der Speicher

- **Huge dimension**:
  48 GW installed capacity with ca.
  120 TWh/a electric power
  (depends on weather year)
- **Short-term storage**:
  possible storage of excess RES in-feed from Germany in Scandinavia
- **Long-term storage**:
  balance of seasonal differences
- **alternatives**:
  storage potential in the Alps, by batteries or power-to-gas relatively low in the medium run

There is potential for additional interconnector projects to tap the huge Scandinavian storage capacities.

50hertz

Challenges for combining offshore wind connections with interconnectors

Different incentive schemes for interconnectors and offshore wind park connections in Germany

Connections for offshore wind parks

- Legal obligation for TSOs to connect offshore wind parks
- Planning in Offshore Network Development Plan
- Limited penalty payments for delayed connection
- Cost-based renumeration for investment the same as for other asset investments

Interconnectors

- Investment depends on detection of social economic welfare in cost-benefit analysis
- Agreement of partner TSO needed
- Inclusion in National Grid Development Plan (onshore) and European TYNDP necessary for regulatory approval
- Cost-based renumeration the same as for other investments
- No special regulatory incentive for offshore interconnectors and/or links integrating wind parks

Offshore wind park connections and interconnectors are set up in different incentive and permission schemes. There are no specific incentives for setting up an offshore meshed grid.

Potential barriers for a Baltic offshore grid

- **Planning and decision-making**
  - How to handle the risk for highly increased complexity of projects with several transmission system operators, regulatory schemes, wind park stakeholders and national interests?
  - Stable political, economic, system-related drivers for partner-TSOs?
  - Do interconnections of wind parks allow for sufficiently beneficial trading capacities?
  - Which additional incentives are available?
- **Technical**
  - Coherent decisions for AC/DC solutions and connections of asynchronous Scandinavian, Baltic and Continental grid?
  - Compatibility of converters?
  - Availability of DC breakers?
  - Correct choice of substation and platform locations?
- **Operation**
  - How to coordinate transmission capacity trading with offshore wind park infeeds?

Regulatory

is priority of wind in-feed to cross-border trade guaranteed?

Conclusions

- **A Baltic offshore grid is an interesting long-term development option:** 50Hertz tests its operational implications in the Combined Grid Solution project.

- **The current incentive scheme for wind park connections and interconnectors seems sufficient to achieve renewables integration and trade capacities**. However, special incentives could boost a meshed offshore grid.

- **Benefits of a meshed offshore grid must clearly outweigh the current preference for point-to-point connections.** They have to address economic, technical, regulatory and operational challenges.

- The new regulations under the **Clean Energy Package must guarantee the priority of offshore wind in-feed in combined grids.**