Integrated grid projects and offshore wind
A TSO perspective
Agenda

1. Renewables development in the 50Hertz control area
2. New 50Hertz offshore interconnectors
3. Drivers for interconnectors
4. Challenges for combining offshore wind connections with interconnectors
Renewables development in the 50Hertz control area
# 50Hertz at a glance

<table>
<thead>
<tr>
<th></th>
<th>2010 (share Germany)</th>
<th>2017/18 (share Germany)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grid area</strong></td>
<td>109,589 km² (~31%)</td>
<td>109,619 km² (~31%)¹</td>
</tr>
<tr>
<td><strong>Length of lines</strong></td>
<td>9,800 km (~30 %)</td>
<td>10,200 km (~30 %)¹</td>
</tr>
<tr>
<td><strong>Max. load</strong></td>
<td>~ 17 GW (~20 %)</td>
<td>~ 16 GW (~20 %)¹</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>~ 98 TWh (~20 %)</td>
<td>~ 96 TWh (~20 %)*</td>
</tr>
<tr>
<td><strong>Installed capacities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- of which Renewables</td>
<td>38,354 MW (~35%)</td>
<td>54,069 MW (~26%)¹</td>
</tr>
<tr>
<td>- of which Wind</td>
<td>15,491 MW (~30%)</td>
<td>32,352 MW (~29%)*</td>
</tr>
<tr>
<td></td>
<td>11,318 MW (~40%)</td>
<td>19,414 MW (~35%)*</td>
</tr>
<tr>
<td><strong>RES share in power consumption</strong></td>
<td>~ 25 %</td>
<td>~ 55.0 %*</td>
</tr>
<tr>
<td><strong>Turnover</strong></td>
<td>5.6 bn. €</td>
<td>9.9 bn. €¹</td>
</tr>
<tr>
<td>- of which Grid</td>
<td>0.6 bn. €</td>
<td>1.3 bn. €¹</td>
</tr>
<tr>
<td><strong>Employees</strong></td>
<td>643</td>
<td>1,043¹</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Installed capacities end of 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind onshore</td>
</tr>
<tr>
<td>18.335 MW</td>
</tr>
<tr>
<td>Wind offshore</td>
</tr>
<tr>
<td>1.066 MW</td>
</tr>
<tr>
<td>Solar PV</td>
</tr>
<tr>
<td>11.157 MW</td>
</tr>
<tr>
<td>Biomass</td>
</tr>
<tr>
<td>1.921 MW</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td>450 MW</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>32.931 MW</td>
</tr>
</tbody>
</table>

Past and Future projections:
- **2018**: Total installed capacities 32.931 MW
- **2020**: Total installed capacities 34.230 MW
- **2025**: Total installed capacities 39.630 MW
- **2030**: Total installed capacities 44.950 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)**

<table>
<thead>
<tr>
<th>Year</th>
<th>RES Feed-in (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>25</td>
</tr>
<tr>
<td>2011</td>
<td>28</td>
</tr>
<tr>
<td>2012</td>
<td>35</td>
</tr>
<tr>
<td>2013</td>
<td>37</td>
</tr>
<tr>
<td>2014</td>
<td>40</td>
</tr>
<tr>
<td>2015</td>
<td>48</td>
</tr>
<tr>
<td>2016</td>
<td>46</td>
</tr>
<tr>
<td>2017</td>
<td>51</td>
</tr>
<tr>
<td>2018</td>
<td>54*</td>
</tr>
</tbody>
</table>

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

- Wind onshore: 59.3%
- Wind offshore: 20.3%
- Solar PV: 16.3%
- Biomass: 2.7%
- Gas (renewable): 1.0%
- Hydropower: 0.3%

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

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

*Integrated grid projects and offshore wind – Baltic InteGrid Conference – Jonas Kraeusel*
Offshore wind contributes to the ambitious goals in renewable generation of Germany and Europe

### EU targets
- **2030**: 40%

### German targets
- **2020**: 40%
- **2030**: 55%
- **2050**: 80-95%

### CO₂ emission reduction\(^1\)
- **2017**: 27.7%

### RES share in power consumption
- **2030**: 27%
- **DE 2017**: 36.2%
- **50Hertz 2017**: 53%

### Efficiency (reduction of power consumption\(^2\))
- **2030**: 27%
- **2016**: 6.3%
- **2018**: 7 op.

### Nuclear
- **2020**: 20%
- **Phase-out until 2022**

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1 compared to 1990 levels (ratification of the Kyoto protocol)
2 compared to 2008 levels
Offshore projects in the Baltic Sea (I/II)

<table>
<thead>
<tr>
<th>#</th>
<th>Project Description</th>
<th>Commissioning</th>
<th>Capacity/Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kontek interconnector</td>
<td>1996</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Baltic 1</td>
<td>2011</td>
<td>48 MW – 150 kV AC</td>
</tr>
<tr>
<td>3</td>
<td>Baltic 2</td>
<td>2015</td>
<td>288 MW – 150 kV AC</td>
</tr>
<tr>
<td>4</td>
<td>Wikinger (Cluster Westlich Adlergrund, Ostwind 1)</td>
<td>12/2017</td>
<td>350 MW – 220 kV AC</td>
</tr>
<tr>
<td>5</td>
<td>Arkona (Cluster Westlich Adlergrund, Ostwind 1)</td>
<td>09/2018</td>
<td>385 MW – 220 kV AC</td>
</tr>
<tr>
<td>6</td>
<td>Kriegers Flak Combined Grid Solution (KF CGS)</td>
<td>Q1/2019</td>
<td>400 MW DC (VSC B2B Konverter) 150 kV AC (Cross Connection)</td>
</tr>
</tbody>
</table>
Offshore projects in the Baltic Sea (II/II)

### Arcadis Ost 1 (Cl. Westl. Adlergrund 2, Ostwind 2)
- **Planned Commissioning**: 2021/2022
- **Capacity/Technology**: 247 MW – 220 kV AC

### Baltic Eagle (Cl. Westl. Adlergrund 2, Ostwind 2)
- **Planned Commissioning**: 2021/2022
- **Capacity/Technology**: 476 MW – 220 kV AC

### Offshore test site
- **Possible Commissioning**
- **Planned Capacity/Technology**: ≈ 300 MW – 220 kV AC

### Hansa PowerBridge interconnector
- **Planned Commissioning**: 2025/2026
- **Planned Capacity/Technology**: ≈ 700 MW – 300 kV DC

### OST-6-1
- **Possible Commissioning**
- **Planned Capacity/Technology**: 3 x 300 MW – 220 kV AC

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**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)
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
  - Permanent and reliable availability of trading capacity
  - No additional complexity 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

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

EU expert commission 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

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

**Interconnections to storage centres**

- **Nordlink**
  - 1,400 MW
  - ab 2020

- **Baltic Cable**
  - 600 MW
  - seit 1994

- **Kriegers Flak (CGS)**
  - 400 MW
  - ab 2019

- **Kontek**
  - 600 MW
  - seit 1996

- **Hansa Power Bridge I**
  - 700 MW
  - ab 2025/26

**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
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.