Offshore wind in the Nordics
Case: Tahkoluoto offshore wind demonstration project

WavEC Seminar 2016
Toni Sulameri, Suomen Hyötytuuli Oy
The Nordic power system

- Finland’s main grid is part of the synchronous inter-Nordic power system together with the systems of Sweden, Norway and eastern Denmark.
- The Nordic system is connected with other countries through several DC transmission connections.
- DC connections from Russia and Estonia to Finland link the Nordic power system with the Russian and Baltic systems.
- The system is also connected to the system in Central Europe via DC transmission links.
Power transmission network in Finland
Planned grid expansion in the region
The grid

Source: nordregio.se
Nord Pool power market

- Owned by transmission system operators in Finland, Sweden, Denmark and the Baltic countries
- Trading in both day-ahead and intraday markets in nine European countries
- 380 companies from 20 countries trade on the markets
- A total of 489 TWh of power traded in 2015

Source: nordpoolspot.com
European wind investments 2000 - 2015

Source: Bloomberg New Energy Finance, 2016
Offshore wind in Baltic Sea Region

- Offshore wind energy in the Baltic Sea Region has a potential of 130 GW.
- Favourable circumstances result in lower installation and grid infrastructure costs; relatively shallow waters, lower wave height and shorter distances to the shore than in the North Sea.
- By 2030, up to 12,2 GW offshore wind capacity can be installed in the Baltic Sea Region.
- Only about 1,1 GW was installed in 2014.

Source: the Baltic Sea Region Energy Cooperation (BASREC), interreg-baltic.eu
Northern Baltic Region – a different market

<table>
<thead>
<tr>
<th>Region</th>
<th>North Sea</th>
<th>Southern Baltic</th>
<th>Northern Baltic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to coast</td>
<td>Long</td>
<td>Long / moderate 10...40</td>
<td>Moderate / short 5...25</td>
</tr>
<tr>
<td>Water depth range</td>
<td>20...40</td>
<td>10...40</td>
<td>5...25</td>
</tr>
<tr>
<td>Tide</td>
<td>Yes</td>
<td>No / insignificant</td>
<td>No</td>
</tr>
<tr>
<td>Swell</td>
<td>Yes</td>
<td>No / insignificant</td>
<td>No</td>
</tr>
<tr>
<td>Max wave</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Mean wind</td>
<td>IEC I</td>
<td>IEC I</td>
<td>IEC II</td>
</tr>
<tr>
<td>Extreme wind</td>
<td>IEC I</td>
<td>IEC I</td>
<td>IEC II</td>
</tr>
<tr>
<td>Water salinity</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Salt spray</td>
<td>Yes</td>
<td>Some</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Corroding air</td>
<td>Yes</td>
<td>Some</td>
<td>Insignificant?</td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>-10...+30</td>
<td>-10...+30</td>
<td>-30...+30</td>
</tr>
<tr>
<td>Drift ice</td>
<td>No</td>
<td>Some</td>
<td>Yes</td>
</tr>
<tr>
<td>Pack ice</td>
<td>No</td>
<td>No / insignificant</td>
<td>Yes</td>
</tr>
<tr>
<td>Turbine design</td>
<td>Offshore</td>
<td>Offshore / semi-offshore</td>
<td>Onshore / semi-offshore</td>
</tr>
</tbody>
</table>

Cold Climate Version
Baltic Sea Region offshore potential in MW

Source: the Baltic Sea Region Energy Cooperation (BASREC)

<table>
<thead>
<tr>
<th>Country</th>
<th>Constrained capacity [MW] - very high score areas (+40)</th>
<th>Constrained capacity [MW] - high score areas (35-39)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capacity after hard constraints</td>
<td>Capacity after excl. protected areas</td>
</tr>
<tr>
<td>Denmark</td>
<td>1,607</td>
<td>201</td>
</tr>
<tr>
<td>Estonia</td>
<td>966</td>
<td>83</td>
</tr>
<tr>
<td>Finland</td>
<td>17,883</td>
<td>16,651</td>
</tr>
<tr>
<td>Germany</td>
<td>87</td>
<td>-</td>
</tr>
<tr>
<td>Latvia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lithuania</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poland</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Russia (Kaliningrad) + Leningrad prov.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>203</td>
<td>-</td>
</tr>
<tr>
<td>Total (MW)</td>
<td>20,746</td>
<td>16,935</td>
</tr>
</tbody>
</table>
Baltic offshore wind potential

The "golden sites"

Wind power development in Finland

• Development done by companies with risks
• Grid connection, cables and stations made by investors
• Feeding tariff for 12 years (currently closed) 83.5 €/MWh
Tahkoluoto
Offshore Wind Farm

- Located in Pori, Finland
- 10 x 4 MW
- Estimated annual power production approx. 155 GWh
- Average power production 43 % of the maximum capacity
- Investment of approx. 120 M€
Challenging arctic conditions

- Finnish offshore wind demonstration project collects lessons learned
- The effects of drifting ice
- Combination of ice and wave loads
Why build offshore wind in this region?

- With near-shore solutions in the Baltic Sea conditions, it is possible to reach a 30% lower cost level compared to the North Sea.
- Strong grid connection points in coastline
- Tahkoluoto demonstration costs 94,8 €/MWh for 12 years > cheapest offshore energy in Europe.
- Targeting a factor cost level of 50 euros/MWh
Tahkoluoto offshore pilot

- Built 2010
- Siemens 2.3 MW offshore wind turbine
- Hub height 80 m, rotor diameter 101 m
- Distance from shore 1.2 km, water depth 9 meters
- 20 kV electric cable
- Gravity-based steel foundation
- Average production 9.36 GWh/year
Turbines

• 10 x 4 MW Siemens offshore turbine SWT-4.0-130
• Rotor diameter 130 m
• Hub height 90,75 m
• 4 MW installed fleet 80 turbines, 3,6 MW 1600 turbines
Gravity-based steel foundations
Foundations manufactured locally by Technip Offshore Finland
Marine operations

• Belgium-based Jan DeNul Group as main contractor
• Subsea works: dredging and trenching
• Foundation installation
• Turbine installation
• Marine coordination

Photo: Jan De Nul
Offshore cable

- Marine subsea power cable
- 3-phase 240/30kV, 24 fiber optic
- Approx. 15 kilometres
- Thickness approx. 110 mm
- Manufacturing in Finland by Prysmian Group starts Oct 2016
Dredging and trenching, mass replacement, compaction
Foundation installation
Filling of foundations
Cabling, erosion protection
Turbine erection
Commissioning
Bird radar technology in Tahkoluoto

- Robin Radar 3D-Flex radar system completed with bird identification software
- Detects small birds up to 3,5 km’s distance, large single birds up to 10 km
- Can be used to slow down wind turbines
- Collects valuable, useful data during seven years