DANISH EXPERIENCE
- HOW TO REACH A > 40% WIND ENERGY SHARE -

1st internat Conference on Large Scale RES integration in India

Antje Orths, Energinet
Development in RES

<table>
<thead>
<tr>
<th></th>
<th>2015 GWh</th>
<th>2016 GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net electricity generation</td>
<td>27,704</td>
<td>28,930</td>
</tr>
<tr>
<td>Net Import</td>
<td>5,912</td>
<td>5,057</td>
</tr>
<tr>
<td>Consumption (incl grid losses)</td>
<td>33,616</td>
<td>33,987</td>
</tr>
</tbody>
</table>

**Breakdown of electricity generation**

<table>
<thead>
<tr>
<th></th>
<th>2015 GWh</th>
<th>2016 GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind, solar and hydro electric power</td>
<td>14,133</td>
<td>12,782</td>
</tr>
<tr>
<td>605</td>
<td>744</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Electricity from thermal Generation based on biofuels</td>
<td>3,789</td>
<td>4,266</td>
</tr>
<tr>
<td>Electricity from thermal Generation based on non RE fuels</td>
<td>9,159</td>
<td>11,119</td>
</tr>
</tbody>
</table>

**Share of RES**

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind power share of net generation</td>
<td>51,0</td>
<td>44,2</td>
</tr>
<tr>
<td>Wind power share of consumption</td>
<td>42,0</td>
<td>37,6</td>
</tr>
<tr>
<td>RE share of net generation</td>
<td>66,9</td>
<td>61,6</td>
</tr>
<tr>
<td>RE share of consumption</td>
<td>55,2</td>
<td>52,4</td>
</tr>
</tbody>
</table>
Denmark is located between a thermal- and a hydro-dominated power system. This makes Denmark a “transit-corridor”.

Energinet.dk operates Eastern – and Western Denmark independently in two different synchronous power systems (Nordic and Continental Europe).
### POWER BALANCE 2016

**Two synchronous areas**

#### West:
- **Net Consumption**: 1280 - 3620 MW
- **Primary power stations**: 2320 MW
- **Local CHP plants**: 1010 MW
- **Wind turbines**: 3710 MW
- **PV**: 410 MW

#### East:
- **Net Consumption**: 860- 2400 MW
- **Primary power stations**: 1880 MW
- **Local CHP plants**: 480 MW
- **Wind turbines**: 1010 MW
- **PV**: 210 MW

<table>
<thead>
<tr>
<th>Relation</th>
<th>DKW</th>
<th>DKE</th>
<th>DK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export capacity/ installed gen.</td>
<td>64</td>
<td>81</td>
<td>59</td>
</tr>
<tr>
<td>Import capacity/ peak load</td>
<td>122</td>
<td>104</td>
<td>95</td>
</tr>
</tbody>
</table>

*Maximum production*

2016: 37.6% el-consumption covered by Wind
THE ENERGY SYSTEM IN DENMARK IS CHANGING

• By 2020, wind power will constitute 50% of the electricity consumption
• By 2050, Denmark must be completely independent of fossil fuels

Strategic commitments of Energinet:
- Security of supply
- Efficient green transition
- Healthy investment climate
DEVELOPMENT IN FUEL CONSUMPTION, DEMAND AND GENERATION

Fuel for electricity generation

Fossil fuel: -70%

Demand and generation

Wind power/Demand = 42%
TOOLBOX FOR EFFICIENT WIND POWER INTEGRATION IN DENMARK

- Strong transmission grids and interconnectors
- International electricity markets
- Flexible generation system
- Specialized forecasting and operational planning tools
How to balance a system with wind variation between ~0 and exceeding demand?
A MARKET DRIVEN DYNAMIC DISPATCH

No large power plants in Denmark West
EXAMPLE: HIGH WINDS – LOW PRICES – NO LARGE POWER PLANTS in DK West

- Large plants: 10 MW
- Local plants: 246 MW
- Wind power & PV: 2,867 MW
- Net exchange, export: 210 MW
- Demand: 2,913 MW

Map showing wind power and PV distribution with different energy values in DKK/MWh.
ALSO WIND FARMS REACT ON MARKET PRICES
HIGH FLEXIBILITY OF POWER PLANTS

Operational range:
10–100%

Regulating rate:
3-4% per minute

Technical key data of Esbjergværket CHP Plant

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Commissioned</td>
<td>1992</td>
</tr>
<tr>
<td>Max power production (net)</td>
<td>378 MW</td>
</tr>
<tr>
<td>Max district heat production</td>
<td>460 MJ/s</td>
</tr>
<tr>
<td>Coal consumption at full load</td>
<td>120 t/h</td>
</tr>
<tr>
<td>Oil consumption at full load</td>
<td>73 t/h</td>
</tr>
<tr>
<td>Steam pressure</td>
<td>251 bar</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>560 °C</td>
</tr>
</tbody>
</table>

Source: Dong Energy
THE NORDIC ELECTRICITY MARKET

Power producers
Consumer

Financial Markets

Day ahead clearing

12:00
15:00

Intraday Market

0:00

Regulating Power Market

h-1

h

The day before the day of operation

Operating hour

1 hr for TSO to prepare physical balancing

TSO

Power producers
Consumer

...
WIND POWER FORECASTS TO REDUCE IMBALANCES

1 m/s deviation ~ 500 MW

Numerical weather prediction + on-line measurements!

1.5% x 5 GW = 75 MW .... (~10% of DK dimensioning fault)
Operational Planning based on best predictions at any time
• Minimize needs for automatic reserve and ancillary service
• Balance system with least cost resources – slow manual reserves
• Detailed and continuously updated knowledge allows operation closer to the limits
• All operational aspects deliver Security of Supply

More efficient and safe to be prepared than surprised!
RESIDUAL DEMAND IN DENMARK
- HOW BIG, HOW LONG AND HOW OFTEN?

Residual demand = Demand − wind − PV (−tidal)

Week with highest residual demand in 10 years.
No wind, no solar and high demand

Maximum average residual demand in periods of different lengths

Source: energy concept 2030, Energinet.dk (Danish version)
RESIDUAL DEMAND IN DK AND NEIGHBOURING COUNTRIES

**Fixed and flexible residual demand**

**Denmark**

Flexible demand and V2G can de-couple a lot in periods of 1-5 hours, but not much in periods longer than 10 hrs.

**Denmark & Neighbours**

- There is not enough PP capacity in neighbouring countries during the short periods with highest residual demand.
- But flexible demand and V2G might help.

Source: energy concept 2030, Energinet.dk (Danish version)
VALUE CHAIN – FROM RESOURCE TO ENERGY SERVICE
- INTEGRATION OF ELECTRICITY, GAS AND HEAT SYSTEMS -

ENERGY BECOMES SUSTAINABLE
In 2050, all energy in Denmark must come from renewable energy sources
WWW.ENERGINET.DK

THANK YOU!
ENERGINET – STATE-OWNED TRANSMISSION SYSTEM OPERATOR

• Ensure short- and long-term security of supply for electricity and gas
• Ensure well-functioning markets for electricity and gas
• Own, operate and develop the gas and electricity transmission grids
OPERATIONAL PLANNING SYSTEMS TO REDUCE RISKS AND COSTS
- PREDICTED IMBALANCE – ON-LINE UP-DATED

Closing the gap before the operating hour

Predicted Imbalance