Overview of development of cross-border interconnections

2017-10-30

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Member of the Swedish Royal Academy of Engineering Sciences
Where will the energy come from?

<table>
<thead>
<tr>
<th>Fossil fuels</th>
<th>Renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global reserves/resources</td>
<td>Global energy potential per year</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy potential/Global annual energy consumption(^1)</td>
<td>Energy potential/Global annual energy consumption(^1)</td>
</tr>
<tr>
<td>348</td>
<td>2850</td>
</tr>
<tr>
<td>155</td>
<td>200</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
</tr>
</tbody>
</table>

### Energy potential

<table>
<thead>
<tr>
<th>Coal</th>
<th>Natural gas</th>
<th>Crude oil</th>
<th>Global energy demand 2006:</th>
</tr>
</thead>
<tbody>
<tr>
<td>~135,000 EJ</td>
<td>~60,400 EJ</td>
<td>~23,000 EJ</td>
<td>~470 EJ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy potential (amount of energy p. a.)(^2)</th>
<th>technologically utilisable (state of the art)(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar radiation ~1,111,500 EJ</td>
<td>~1,482 EJ</td>
</tr>
<tr>
<td>Wind energy ~78,000 EJ</td>
<td>~195 EJ</td>
</tr>
<tr>
<td>Biomass ~7,800 EJ</td>
<td>~156 EJ</td>
</tr>
<tr>
<td>Geothermal ~1,950 EJ</td>
<td>~390 EJ</td>
</tr>
<tr>
<td>Hydro/tide power ~1,170 EJ</td>
<td>~78 EJ</td>
</tr>
</tbody>
</table>

Source: University of Twente
Europe has already decided
Today 90 % RES

Source: WindEurope
The European power challenge

- Strong expansion of variable renewable production
- Uncoordinated expansion of production
- Different incentive / tax systems
- Loop flows
- Unstable prices

![Figure 4: Import capacity as a % of net generation capacity in 2011](image_url)
Cornestones in European energy policy

Develop a fully operational and interconnected Energy Union to enable energy diversification and guarantee security of supply.

Promote the integration of renewable energies so that 27% of total energy consumption comes from renewable sources, hence reducing energy dependency.

Reduce greenhouse gas emissions by -40% compared to 1990 levels.
The balance / variability challenge

Variation and uncertainty
- Variation in demand
- Grid faults and outage
- Planned maintenance
- RE output fluctuation

System flexibility solutions
- Energy efficiency services
- Demand Response
- Flexible production
- Energy storage
- Import/export

Source: DG Internal Policies 2015
Interconnections key to power balance
Example wind power in Denmark

Figure 6 • Average trade on interconnection lines by wind generation levels, western Denmark, 2015

Source: Adapted from Energinet.dk (2016), Market data
ENTSO-E
Ten Year Network Development Plan 2016

EXECUTIVE REPORT
ENTSO-E

€150bn
investments, of which 70-80 by 2030

50% to 80%
emissions cut depending on the vision

1 to 2 €/MWh
impact on bills due to transmission investment

1.5 to 5 €/MWh
potential reduction in wholesale prices

45 to 60%
RES across 4 Visions for 2030

40%
reduction in congestion hours
ENTSO-E, Ten Year Plan, all projects
Case: INELFE Interconnection France - Spain

- Security of supply
- Increased efficiency
- Economy
- Integration of RES
- Total cost €1.75bn of which EU support €0.70bn
Case: INELFE Interconnection France - Spain

- **SEW**  Savings in generation fuel and operation cost  Meuros/yr
- **RES**  Additional hosting capacity renewable  GWh/yr
- **Losses**  Reduction in losses  GWh/yr
- **CO2**  Change in CO2 emissions  kT/yr

<table>
<thead>
<tr>
<th>Scenario specific CBA indicators</th>
<th>EP2020</th>
<th>Vision 1</th>
<th>Vision 2</th>
<th>Vision 3</th>
<th>Vision 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 SoS (MWh/yr)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>B2 SEW (MEuros/yr)</td>
<td>200 ±30</td>
<td>120 ±20</td>
<td>150 ±20</td>
<td>120 ±30</td>
<td>240 ±30</td>
</tr>
<tr>
<td>B3 RES integration (GWh/yr)</td>
<td>40 ±40</td>
<td>460 ±200</td>
<td>960 ±190</td>
<td>700 ±250</td>
<td>1000 ±140</td>
</tr>
<tr>
<td>B4 Losses (GWh/yr)</td>
<td>700 ±100</td>
<td>800 ±100</td>
<td>1200 ±400</td>
<td>750 ±100</td>
<td>1200 ±200</td>
</tr>
<tr>
<td>B4 Losses (MEuros/yr)</td>
<td>30 ±5</td>
<td>40 ±10</td>
<td>55 ±20</td>
<td>35 ±10</td>
<td>55±20</td>
</tr>
<tr>
<td>B5 CO2 Emissions (kT/year)</td>
<td>2400 ±500</td>
<td>800 ±400</td>
<td>±100</td>
<td>-1000 ±200</td>
<td>-2300 ±200</td>
</tr>
</tbody>
</table>
100% RES electricity (X7): 100% renewable electricity with both large scale and small-scale generation units, as well as links with North Africa. Both large-scale and small-scale storage technologies are needed to balance the variability in renewable generation.
Will transmission investments pay off?

100% RES electricity (X7): 100% renewable electricity with both large scale and small-scale generation units, as well as links with North Africa. Both large-scale and small-scale storage technologies are needed to balance the variability in renewable generation.
ENTSO-E, Ten Year Plan
Observations

• Involves the entire continent

• High number of off-shore cables

• Both onshore and offshore HVDC transmission systems

• All HVDC Systems based on VSC Technology
Market / Price challenge
Market integration, starting with regions

Expected structure of the six RSCs by end of 2017:
- TSO in TSC and Nordic RSC
- TSO in TSC and CORESO
- Nordic RSC (2016)
- Baltic RSC (2016)
- TSC (2008)
- CORESO (2008)
- TSO procuring services from TSC
- SEE-Thessaloniki RSC (2017)
- SCC (2015)

Source: FTI-CL report for ENTSO-E
Lessons learned

• Grid investments is generally a very cost efficient way to improve the electricity system.

• Multiple benefits from interconnectors

• A common system for economical evaluation of projects is essential.

• Value of interconnections is higher the more renewable production is introduced.

• Be aware of technological development, new solutions gives more options.
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