Current and Future Markets and Challenges for Onshore and Offshore Wind in TX

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Agenda

- Texas Tech activities in wind, renewables, grids and energy storage
- Offshore wind in Denmark
- Technology and capacity fact, be careful with the assumptions – especially about the future assumptions
- Territories leading the way
- Offshore challenges
- Storage functionality
- Conclusion
Poul La Cour systematically researched how wind power could support his social vision, bringing the power of electricity to the rural areas.

Education: meteorologist

Published a magazine, established a wind energy society and wind education

For La Cour, the windmill was a power plant.

His inventions included:

- Aerodynamic investigations in a wind tunnel
- Storage in Hydrogen (no grid !)
- Kratosate: a mechanical adjustment of variable load inputs to improve smooth running of a DC motor
About Texas Tech Wind energy

Education at Tech

• 2005 First Wind Energy Graduate Class was offered
• 2007 Wind Science and Engineering PhD
• 2009 Funding by Texas Workforce Commission
• 2010 Graduate Certificate Program – 2 Tracks
• 2011 Bachelor of Science in Wind Energy
• 2017 BSWE Metrics
  • 180 majors
  • 50 minors in Wind Energy (6 courses)
GLEAMM is a $13M award from the State of Texas to test, certify, and develop new electric grid technologies and next generation power electronics.

*Increase Research, Accelerate Innovation, Grow Field Testing at Group NIRE*

- Smart-grid and Smart-home
- Microgrid and Distributed Energy Resources (DER)
- Cybersecurity and Big Data
- Solar
- Battery storage
- Wind
- Phasor measurement units (PMU)
- Weather and energy forecasting
- Silicon carbide design and manufacturing

http://gleamm.org/
Huge real world Microgrid and Energy Test Facility

The Reese Technology Center is a former Air Force Base that has become the well understood electric grid and place for any research, testing, certifying of energy resources.

- Additional Wind Turbines
- 1MW Battery
- DOE/SNL SWIFT Facility
- Commercial prototype test
- Hurlwood Sub-station (3.5MW)
- Battery Test Facility
- Solar Array
- Erskine Sub-station (3.5 going to 10 MW)
- Diesel Generator
- Wolfforth Sub-station (5-15MW)
- Yuma Substation (15MW)
- To Carlisle Sub-station, Xcel, Southwest Power Pool
- Xcel, Southwest Power Pool
Fully open source controls and open source DOE / Sandia wind farm

3 full open source wind turbines, including controls

The Battery Storage System (BSS) uses 18 racks with 256 Li-Ion batteries totaling 4,608 battery cells with a combined energy storage capacity of 1 MW-hr.
Lillegrunden wind farm – 48 turbines, 377 feet tall. Seen 75 feet above sea level from 12 miles away, 24 miles away, this would be under the horizon.

Bridge to Sweden
5 miles

Tunnel to Copenhagen
~ 2.5 miles
First offshore wind turbine, ~1940: concrete and 2-blades

Two technologies that keep bouncing back?

Company F.L Smidth
~1940, Neksø

Company F.L Smidth,
Gedser 1956

Tvind school
1978

Nibe, 1982

Näsudden,
Sweden, 1982

Elsam (Dong)
Tjæreborg, 1989

SEAS (Dong)
Avedøre, 1993

Dong Energy, 3 x Siemens 2.3MW,
Avedøre, 2010

www.windsofchange.dk
ele.aut.ac.i
www.hvidovrevindmoll
aug.dk
Onshore and Offshore fleet capacity factor is increasing
New technology and larger machines

- Capacity factor (ratio of actual energy divided by rated):
  - Nuclear 80 to 90%
  - Coal ~ 70%
  - Natural gas ~39%
- Wind turbines are available 96% to 99% of the time
- Wind energy available is almost uniquely a function of rotor size and wind distribution on the specific site
- Modern wind capacity factor ranges from 40% to 55 % on both land and offshore, mainly due to rotor size

One modern offshore machine produce energy for 3000 US households

1 x 720 feet = 4 x 490 feet = 43 x 130 feet tall turbines

Offshore
8000 kW
720 feet

2014 land base
2000 kW, each
490 feet

1989 “historic”
225 kW, each
130 feet

Today’s typical Mid-West turbines

1980ies California

Denmark get more than 40% of its energy from wind, 10% of it is from 516 offshore wind turbines. Days with more than 100% wind
Denmark all wind turbines:
- 5196 turbines
- 4823 MW
- Produced 9466 GWh in 2013
- 30% of the domestic energy consumption

Offshore wind:
- 1271 GW
- Offshore wind accounts for approx. 10% of the domestic energy consumption

Vindeby:
11 450kW stall wind turbines,
2 km from the coastline
Concrete foundation

North Sea
Horns Rev I
(160MW)

Anholt
(400MW)
Load and generation development in Denmark

Source: www.energinet.dk
Onshore and Offshore fleet capacity factor is increasing
New technology and larger machines (approximate numbers)

<table>
<thead>
<tr>
<th>Where</th>
<th>Capacity factor</th>
<th>Penetration</th>
<th>Maximum</th>
<th>Number of turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>24.3%</td>
<td>4%</td>
<td></td>
<td>341,320</td>
</tr>
<tr>
<td>US</td>
<td>32.9%</td>
<td>5.6%</td>
<td></td>
<td>52,343 (offshore: 6)</td>
</tr>
<tr>
<td>China</td>
<td>19.3%</td>
<td></td>
<td></td>
<td>104,934 (offshore: ~300)</td>
</tr>
<tr>
<td>EU</td>
<td>26.3%</td>
<td>10.4%</td>
<td></td>
<td>~128,000 (offshore: 3,589)</td>
</tr>
<tr>
<td>Texas</td>
<td>34.5%</td>
<td>15.1%</td>
<td>50%</td>
<td>10,700 (offshore: 0)</td>
</tr>
<tr>
<td>DK (offshore)</td>
<td>33.6% (41.4 to 49.4)</td>
<td>42.7%</td>
<td>&gt;140%</td>
<td>5196 (offshore: 512)</td>
</tr>
</tbody>
</table>

Data source:
energynumbers.info/capacity-factors-at-danish-offshore-wind-farms and iea.gov
GWEC, ERCOT, BP Energy statistics
Energinet.dk grid, import and export
First in the water US offshore: Block Island
Regional wind PPA’s
Reducing offshore cost of energy is crucial

Offshore: $199\textsuperscript{*1}
DOE target: $100\textsuperscript{*2} by 2020,

Average retail price
US ~ $100
EU ~ $250

Sources:
2013 Wind Technologies market report, Wiser & Bolinger, LBNL / DOE
*1, Fishermen PPA / NJ public utility board
*2, DOE 2010 target for US offshore wind
Offshore cost of energy, still some challenges

**Figure 6**
Capital and operational expenditures in relation to CoE (own adaptation)

- WTGs: 18%
- Foundations: 38%
- Electrical infrastructure: 19%
- Assembly, installation and project development: 16%
- Operational expenditure: 9%

**Source:** Danish Energy Agency, 2010; Nielsen et al, 2010 and own calculations. CoE is defined as the average cost of electricity production measured in €/MWh during the total lifetime span of the electricity production facilities. Discount rate is 10%.

Source: [http://windpower.org](http://windpower.org) Danish wind power association
Wind energy is competitive – Texas is a world class leader

Gov. Bush signs Texas RPS goal of 2,000 MW

Texas updates RPS goal of 5,800 MW

Texas exceeds 12,000 MW No. 5 world wide 8.3% penetration

Texas exceeds 18,000 MW No. 5 world wide 15.1% penetration

2013 Wind Technologies market report, Wiser & Bolinger, LBNL / DOE
When and where is the power available?

Regionally and timely variations:
Inter-year, yearly, monthly, daily, hourly
Short term weather related (storm, thunderstorm, ice, rain etc.)
Operational / technical variations
The challenge

- **Function**
  - Spatial shift of energy (transmission and delivery)
  - Balancing between sources (wind, solar, fossil, nuclear)
  - Time shift of energy (storage)
  - Load and peak values management
  - Ancillary services support

- **Cost**
  - Meeting demand / market price
  - Storage media lifetime consumptions cost (and efficiency)
  - Turbine lifetime consumption cost
  - System cost and ownership structure

- **Control**
  - Forecasting of potential generation
  - Plant control technology
  - Source control and transmission control
  - Meet market / demand – delivery and price
  - Ownership structures and market pricing
Conclusions

- Denmark has exceed 100% wind many time @around 30%
  - Strong interconnect
  - Strong market
  - One grid operator
- Texas has reached up to 50% wind several times @around 15%
  - Strong market
  - One grid operator
- Offshore wind energy will continue to grow, but fundamentally price and available space play an important role in the US
- On the wind technology side, be careful predicting the future using past data