TEXAS TECH UNIVERSITY

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

U.S. Department of Energy
H2@Scale Workshop
May 23-24, 2017, University of Houston

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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

Electric wind energy
Denmark anno 1896

Poul La Cour systematically researched how wind power could support his social vision, bringing the power of electricity to the rural areas

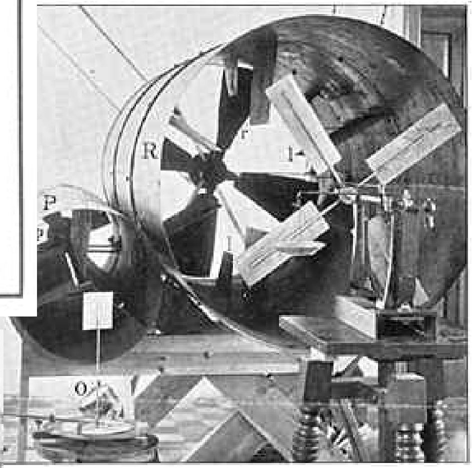
Education: meteorologist

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



Pictures and sources
www.poullacour.dk

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
Global Laboratory for Energy Asset Management and Manufacturing

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

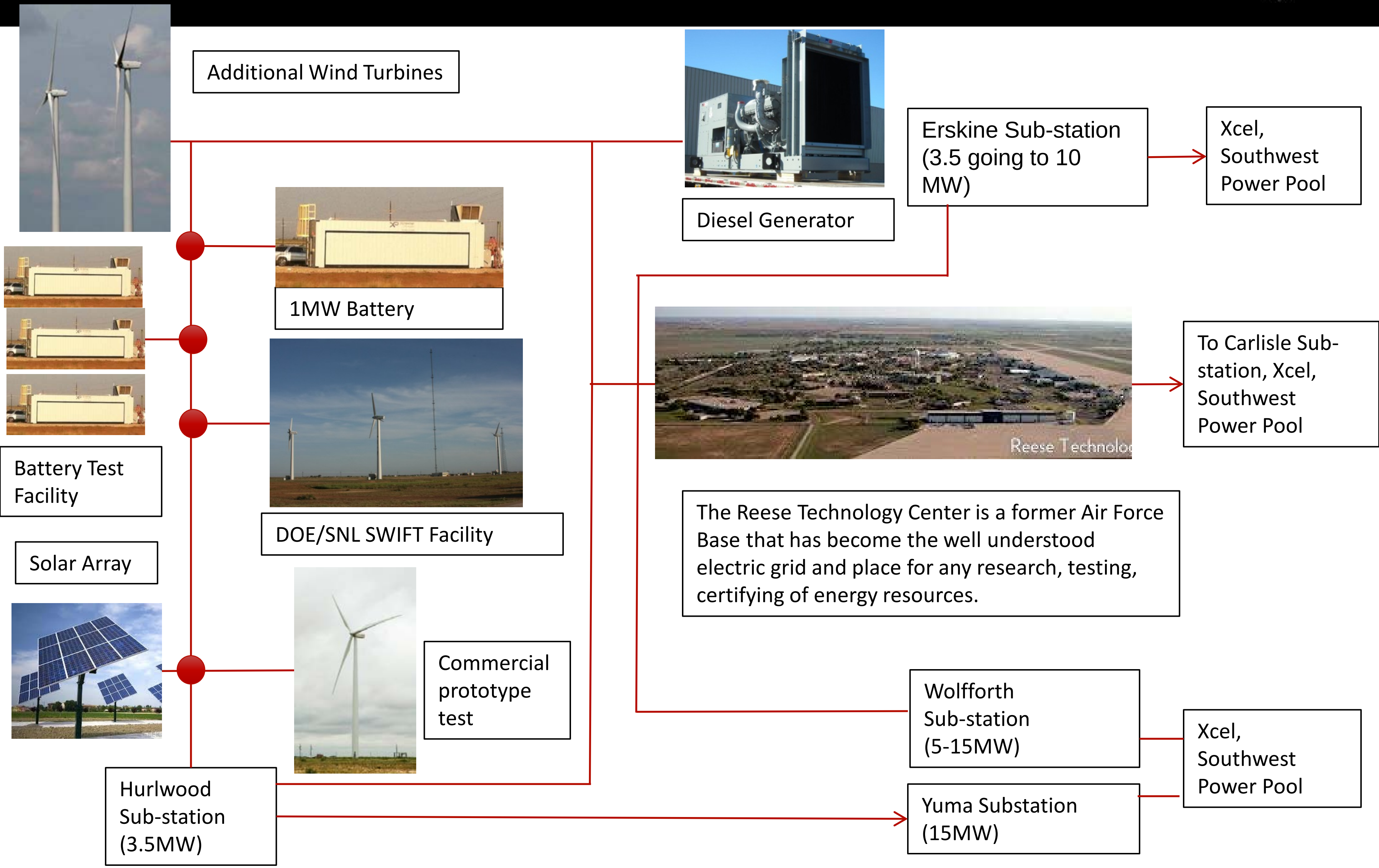
- Smart-grid and Smart-home
- Microgrid and Distributed Energy Resources (DER)
- Cybersecurity and Big Data
- Solar
- Battery storage
- Wind
- Phasor measurement units (PMU)
- Weather and energy forecasting
- Silicon carbide design and manufacturing

GLEAMM
GLOBAL LABORATORY FOR ENERGY ASSET MANAGEMENT AND MANUFACTURING

GROUP NIRE
Renewable Energy Solutions
TM

http://gleamm.org/

Huge real world Microgrid and Energy Test Facility



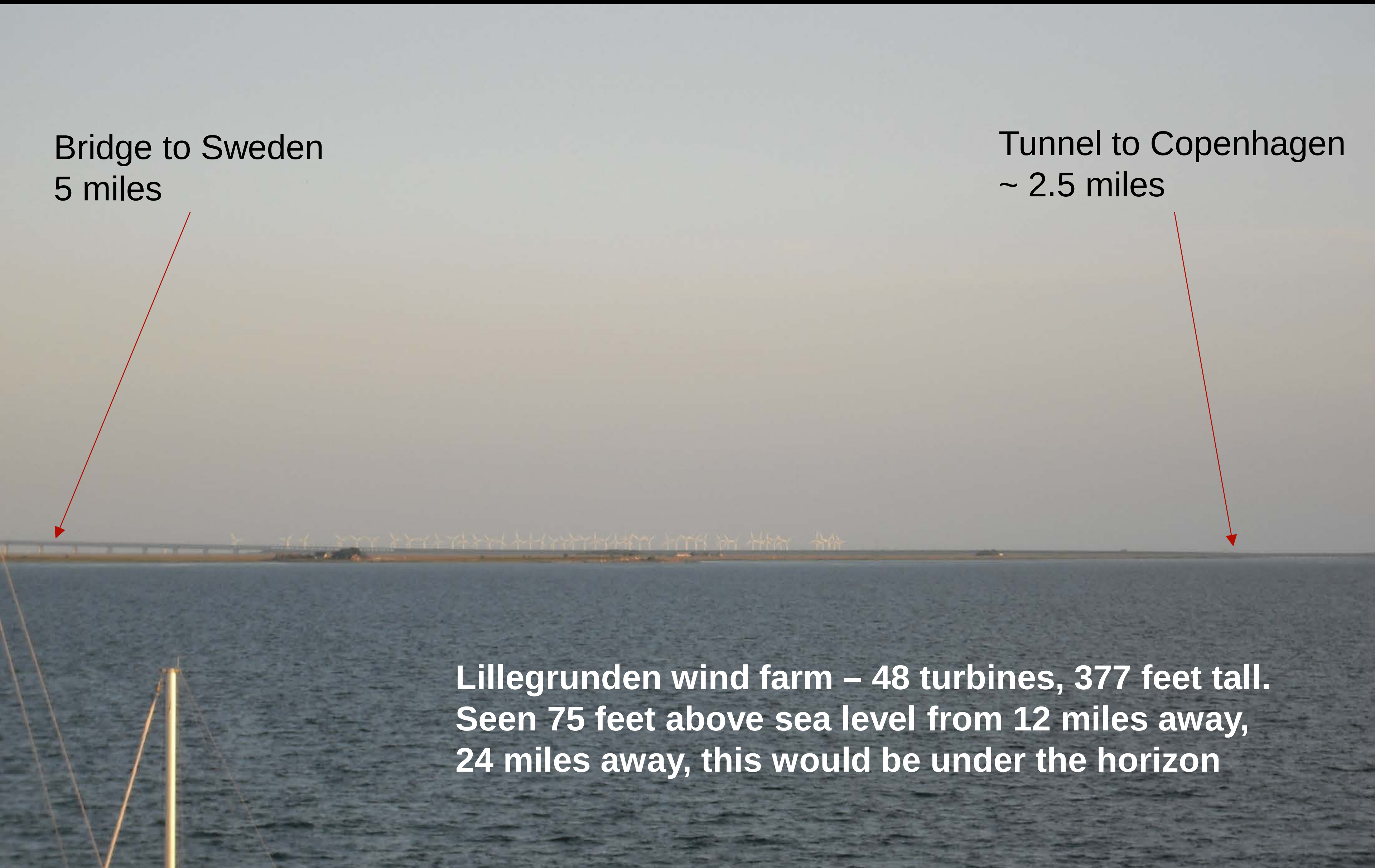
Fully open source controls and open source DOE / Sandia wind farm

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.


Middelgrunden, Denmark

Lillegrunden



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

First offshore wind turbine, ~1940: concrete and 2-blades
Two technologies that keep bouncing back ?

Company F.L Smidth ~1940, Neksø

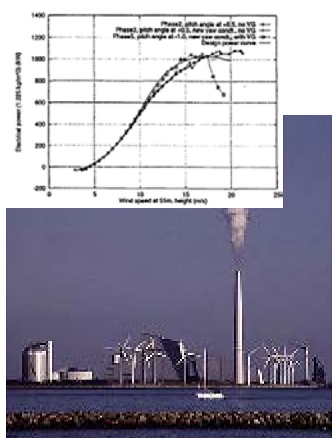
Company F.L Smidth, Gedser 1956

Tvind school 1978

Nibe, 1982

Näsudden, Sweden, 1982

Elsam (Dong) Tjæreborg, 1989



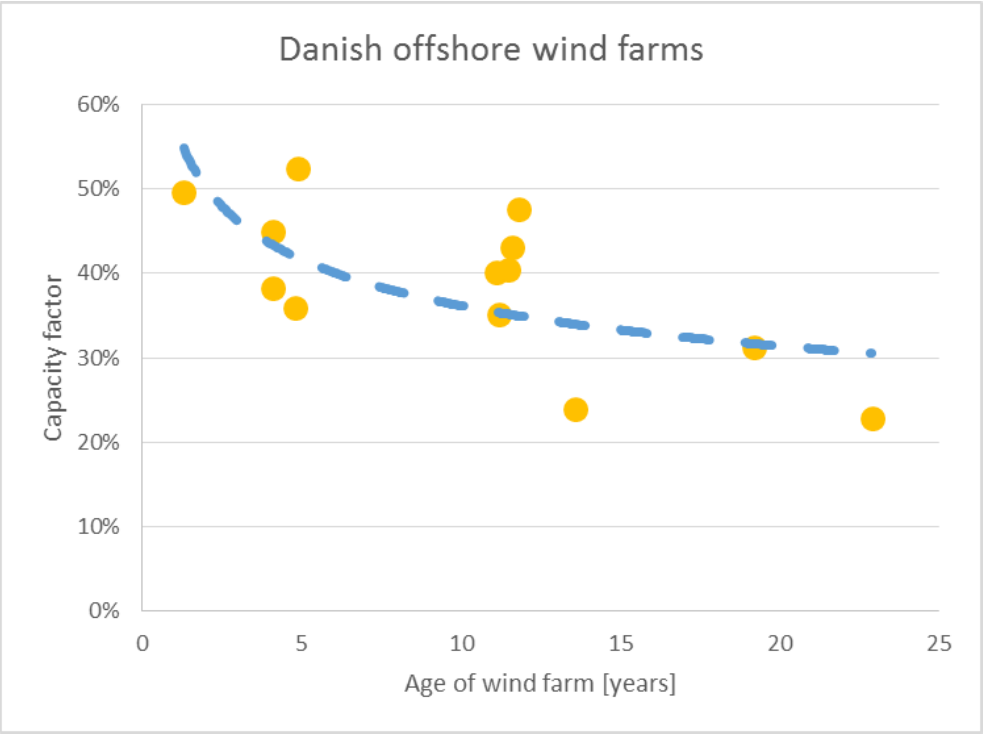
SEAS (Dong) Avedøre, 1993

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

www.windsofchange.dk
ele.aut.ac.i
www.hvidovrevindmollelaug.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

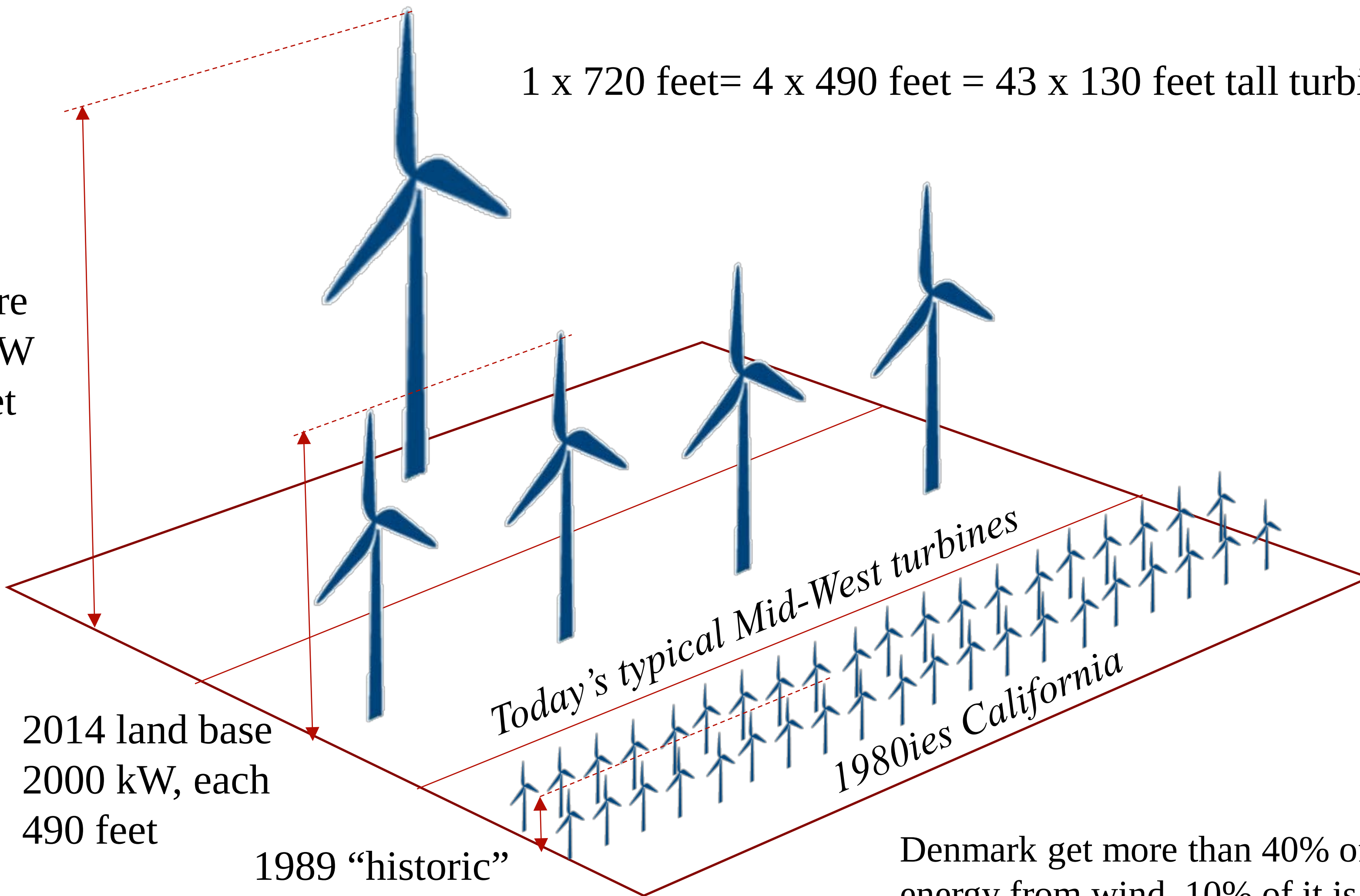


Data source: http://energynumbers.info/capacity-factors-at-danish-offshore-wind-farms and iea.gov

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

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

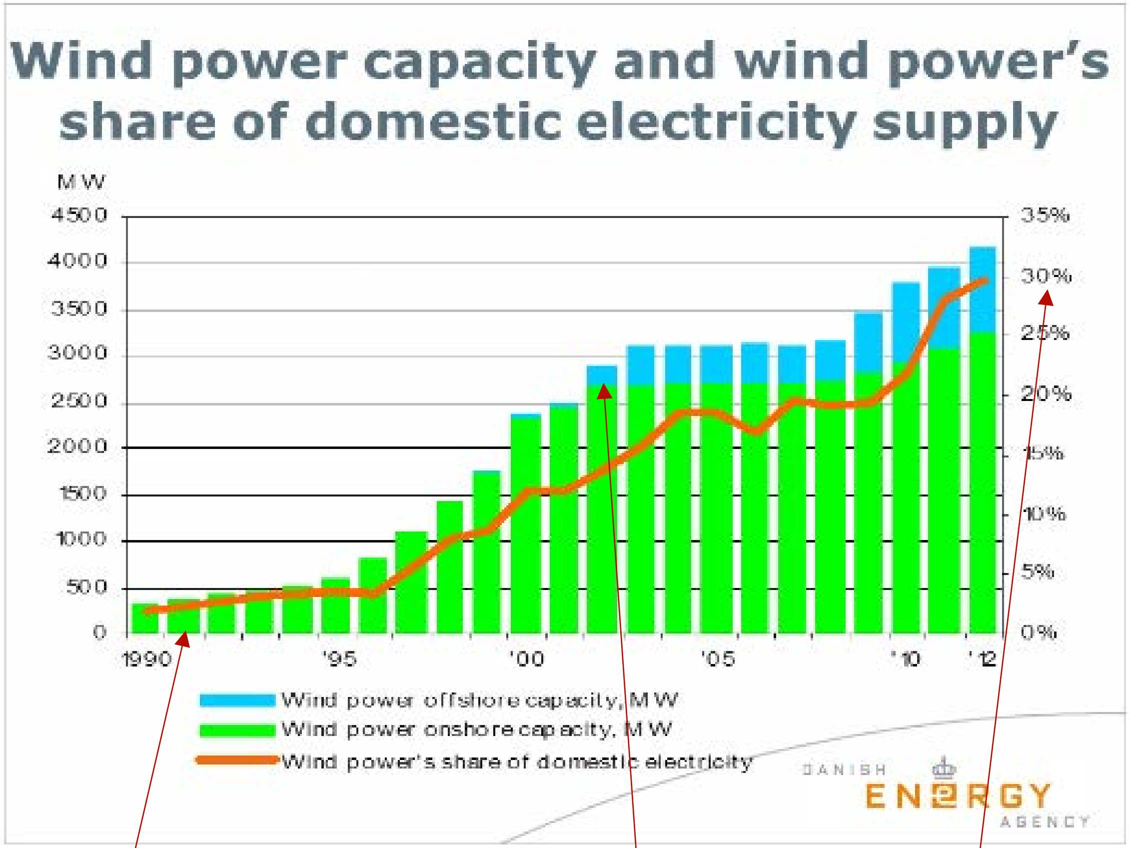
Status from the Danish Energy Agency

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



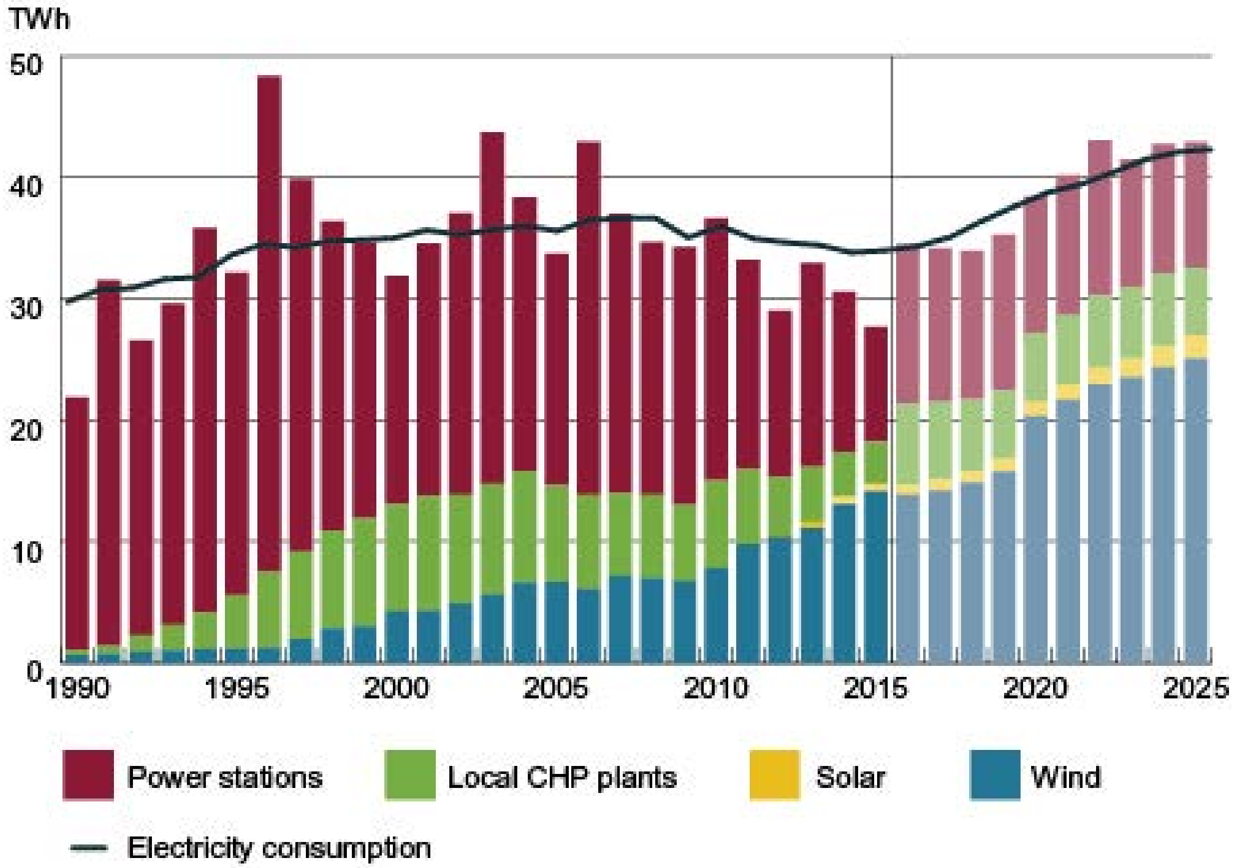
Vindeby:
11 450kW stall wind turbines,
2 km from the coastline
Concrete foundation

North Sea
Horns Rev I
(160MW)

Anholt
(400MW)

http://ens.dk

Load and generation development in Denmark



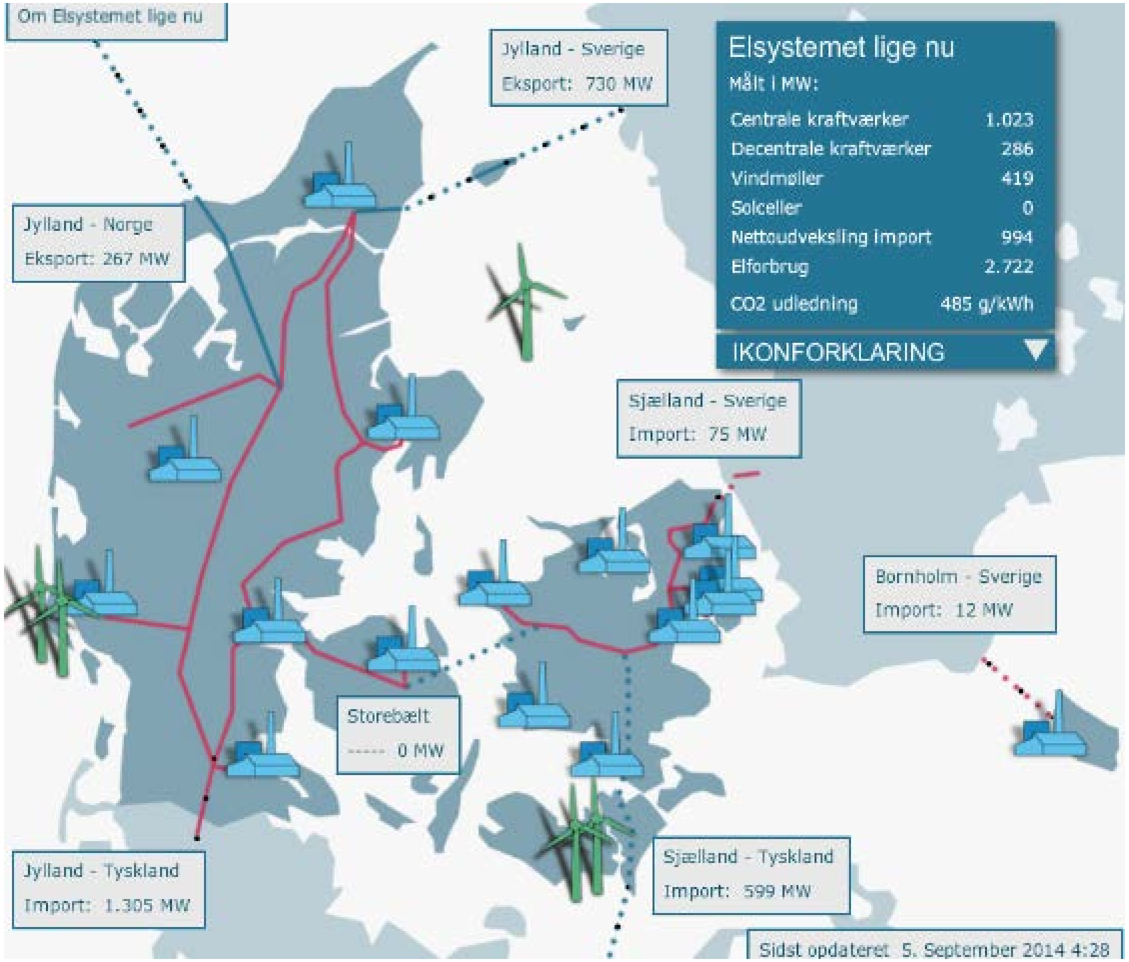
Source: www.energinet.dk

Onshore and Offshore fleet capacity factor is increasing
New technology and larger machines (approximate numbers)

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

Data source:
energynumbers.info/capacity-factors-at-danish-offshore-wind-farms and iea.gov
GWEC, ERCOT, BP Energy statistics

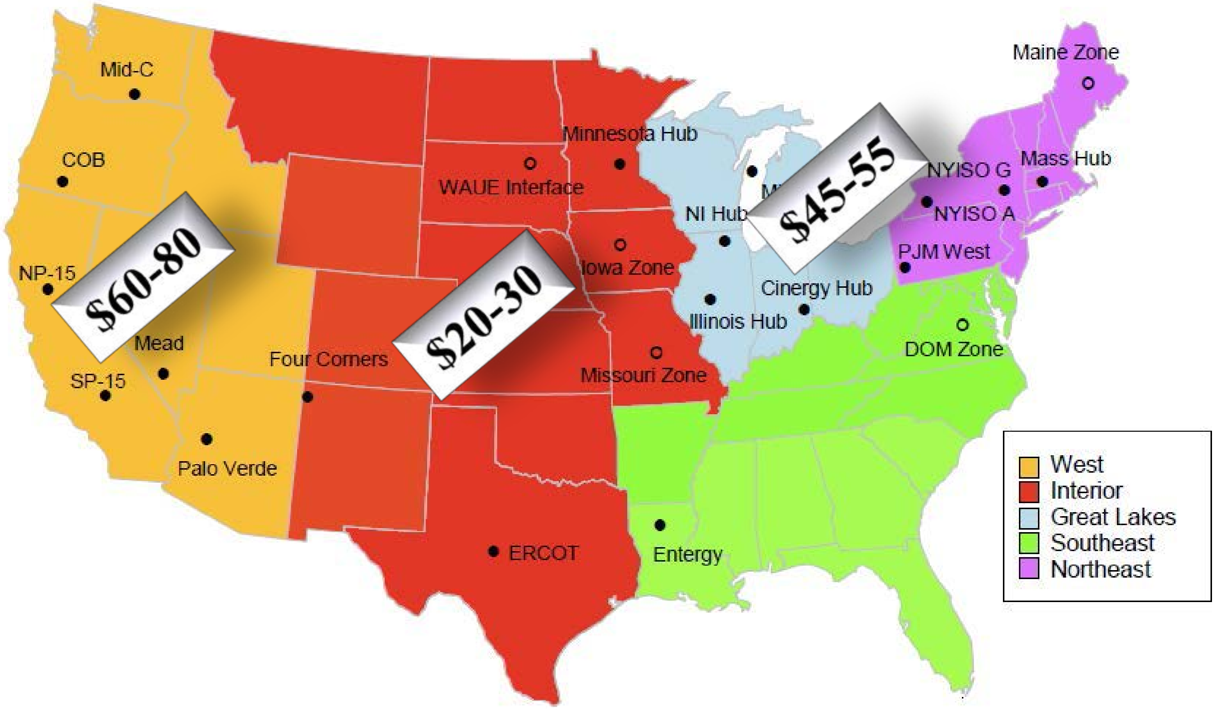
Energinet.dk grid, import and export



First in the water US offshore: Block Island

CleanTechnica

Regional wind PPA's
Reducing offshore cost of energy is crucial



Offshore: $199*1

DOE target: $100*2 by 2020,

Average retail price
US ~ $100
EU ~ $250

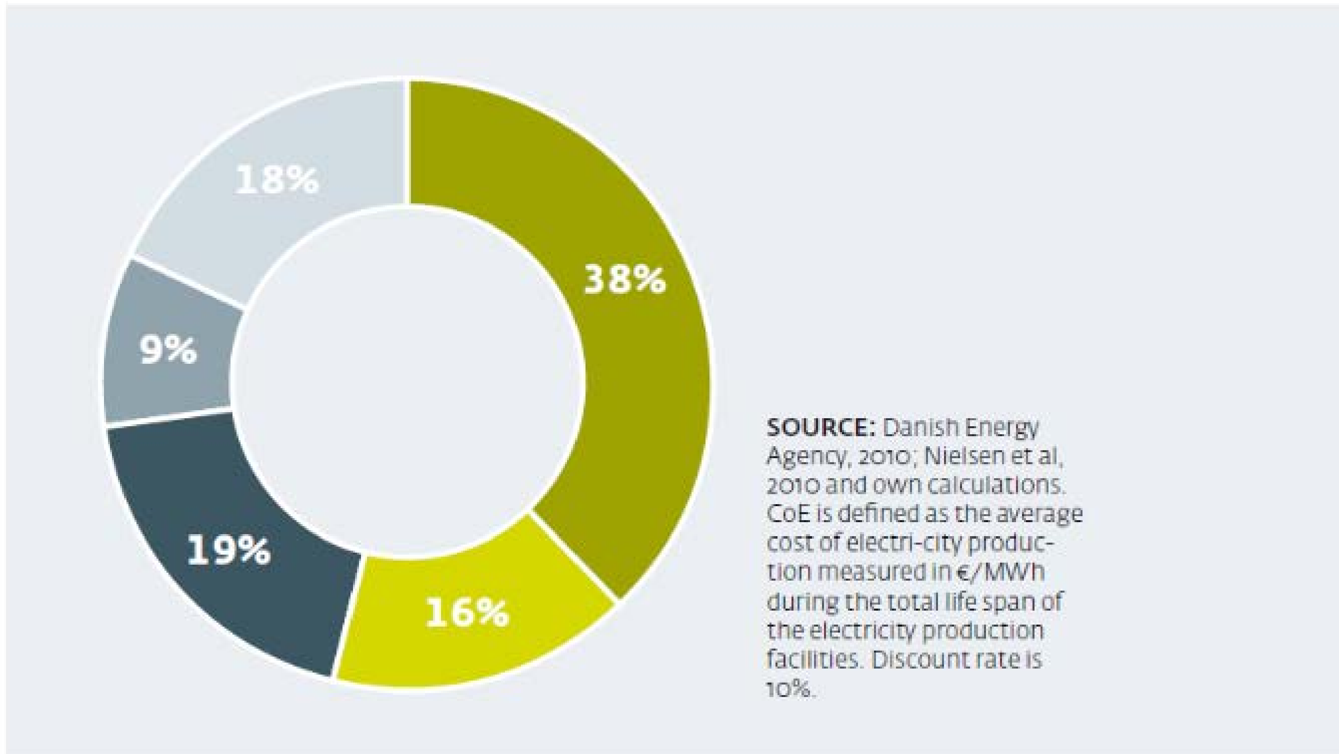
Sources:
2013 Wind Technologies market report, Wiser & Bolinger, LBNL / DOE
*1, Fishermen PPA / NJ public utility board
*2, DOE 2010 target for US offshore wind

Offshore cost of energy, still some challenges

Figure 6

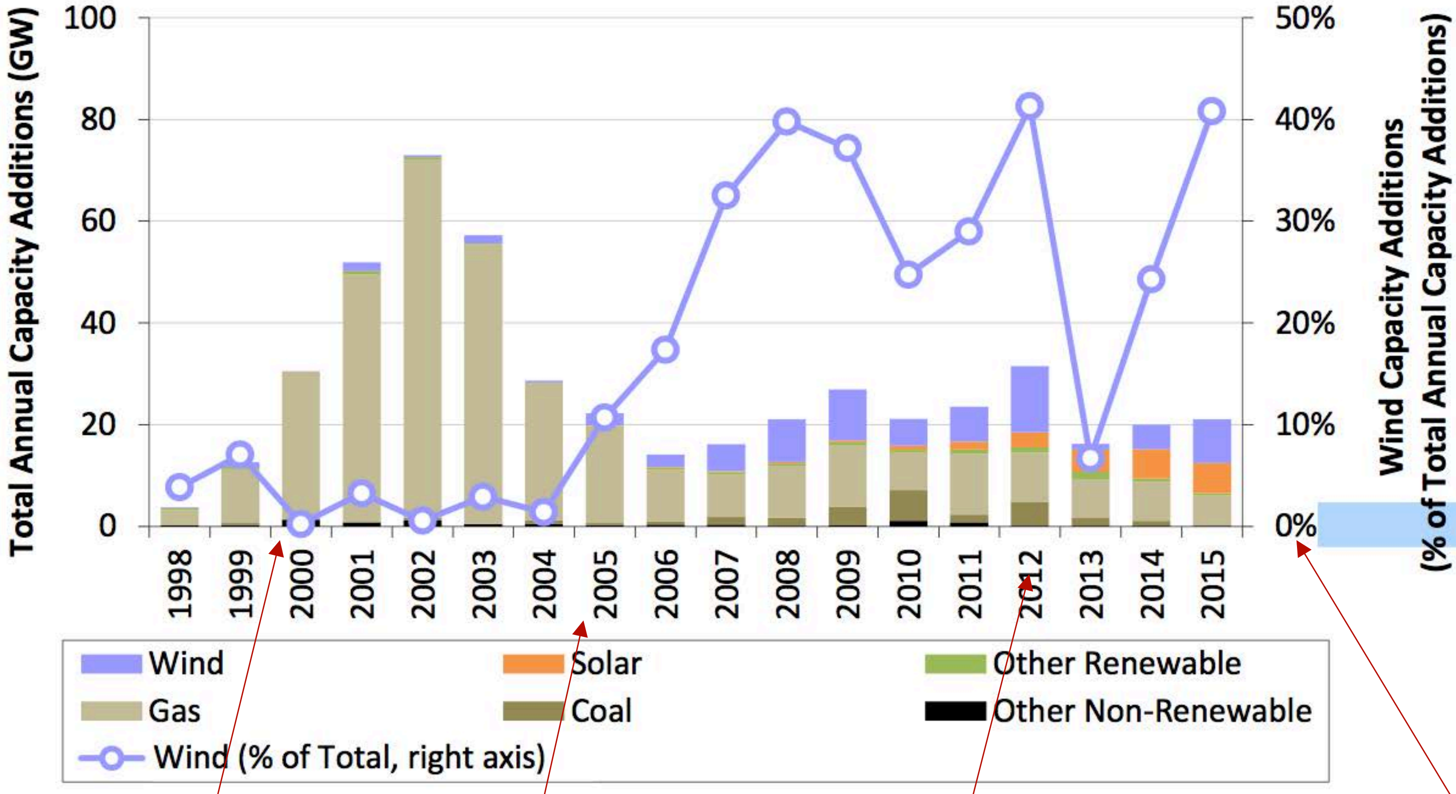
Capital and operational expenditures in relation to CoE (own adaptation)

- WTGs
- Foundations
- Electrical infrastructure
- Assembly, installation and project development
- Operational expenditure



Source: http://windpower.org Danish wind power association

Wind energy is competitive – Texas is a world class leader



Source: ABB, AWEA, GTM Research, Berkeley Lab

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

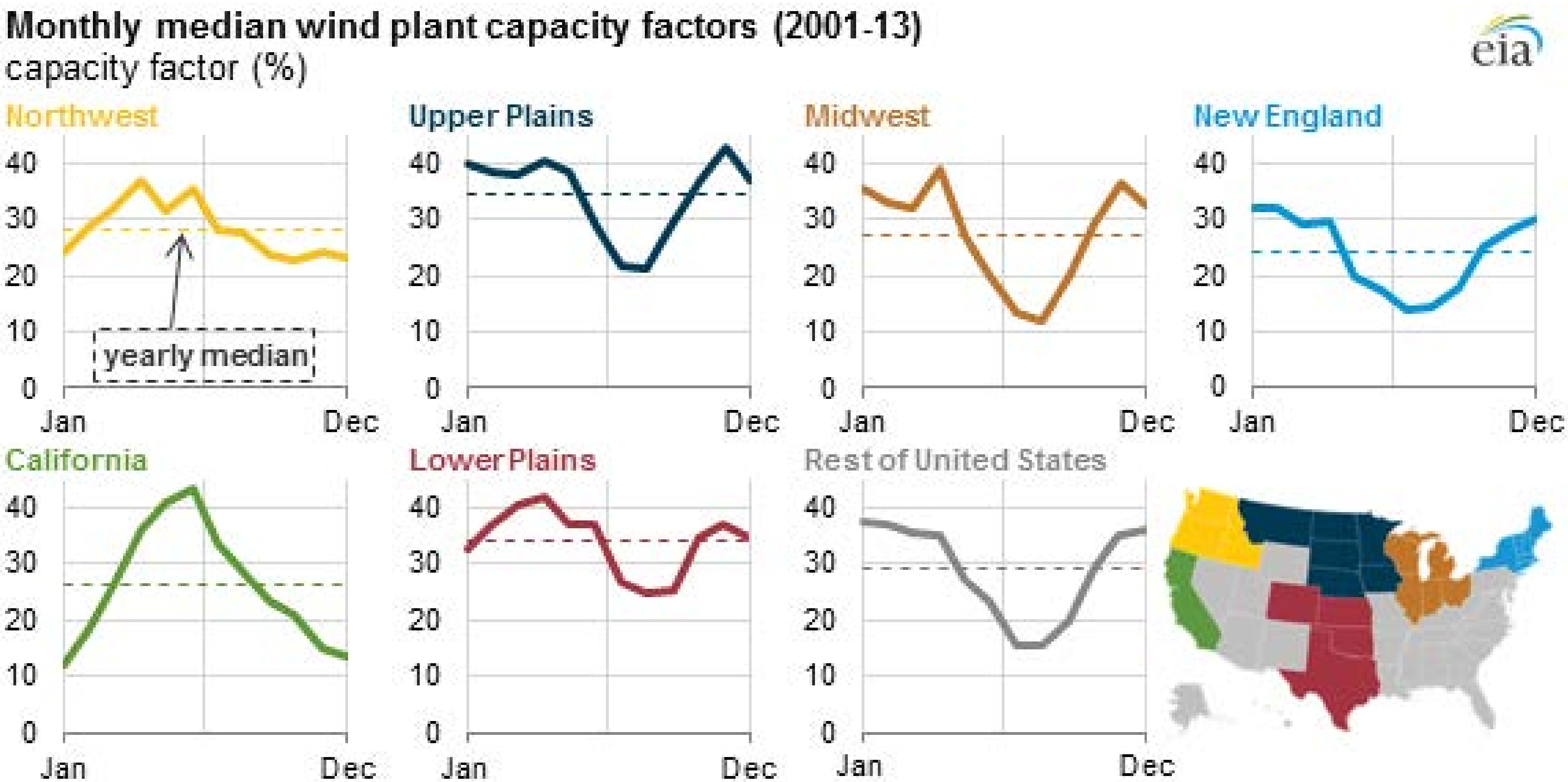
Texas updates RPS goal of 5,800 MW

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

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