Energy Institute

How far can wind go ....?

The Crown Estate

May 2017

Will Apps
Head of Energy Development
Contents

1) The Crown Estate
2) UK Offshore Wind Portfolio
3) A mature industry?
4) Future direction …?
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Who we are

The Crown Estate is an independent commercial business created by Act of Parliament.

- Our capital value is £12.9 billion
- Net profit in 2015/16: £304.1 million

Conscious commercialism defines our approach to business.
• The Crown Estate is a public body with a commercial mandate operating under the statutory requirements of the Crown Estate Act 1961 to manage the hereditary estate of the monarch.

• The assets managed by The Crown Estate are not the property of the Government, nor are they part of the Sovereign’s private estate.
Energy, Minerals & Infrastructure

Gas and CO$_2$ Storage

Wave and Tidal energy

Cables & pipelines

Minerals

Offshore Wind energy
Does not include…

Fisheries

Water column

Hydrocarbons

Public rights of navigation
Offshore Ownership and rights

- Ownership - The Territorial Seabed (to 12nm)
- 50% of the foreshore, in the Rural & Coastal Portfolio
- Rights - to explore and exploit the natural resources of the Continental Shelf (<200 nautical miles)
- Gas Importation and Storage Zone - GISZ (Energy Act 2008)
UK Offshore Wind Portfolio
OSW Spatial distribution 2016 – 2030s

“On current plans we expect to see 10 GW of offshore wind installed by 2020.”

“If [the necessary cost reduction] happens we could support up to 10GW of new offshore wind projects in the 2020s.”

Amber Rudd – DECC Secretary of State, November 2015
Future demand for offshore wind generation

Offshore Wind Scenarios to 2040

- Predicted reductions in cost of electricity
- Energy security (Nuclear delay)
- Low reduction in cost of elect.
- Asset integrity issues

Installed Capacity (MW)

- NG FES Gone Green (July 2016)
- NG FES Slow Progression (July 2016)
- NG FES No Progression (July 2016)
- NG FES Consumer Power (July 2016)
- CCC 5th Carbon Budget 'High Renewables' (Nov 2015)
- CCC 5th Carbon Budget 'High Nuclear' (Nov 2015)
A mature industry …?
What is the 2016 data showing?
Cost Reduction

- £97/MWh for new projects in 2015/16, 32% reduction in 5 years
- £100/MWh by 2020 target achieved 4 years early
- Technology developments have made the largest contribution
- Competition has also driven down costs in the supply chain
- Risk profile and the cost of capital is reducing as confidence in the sector grows

System Performance, Availability & Reliability Analysis

SPARTA by numbers

20 TWh
Produced by portfolio in reporting period

1
Number one
First benchmarking platform for Offshore Wind assets

39.4%
Capacity factor achieved by portfolio in reporting period

93.7%
of installed capacity of UK operational offshore wind farms reporting

1,378
Wind Turbines monitored

19,465
Data points reported in year

76
Unique Key Performance Indicator metrics compiled on monthly basis

Source: ORE Catapult, Portfolio Review 2016
The future direction …
Key events and activity shaping policy

- Contract for Difference Round 2
- Clean Growth Plan
- Offshore Wind Sector Deal (Industrial Strategy)
- Autumn Statement – LCF replacement

"The government recognises the need to limit costs to businesses and households as the UK decarbonises its energy supplies."

"The existing levy control framework has helped to control the costs of low carbon subsidies in recent years, and will be replaced by a new set of controls. These will be set out later in the year."

Treasury Spring Budget 2017
Grid Integration

• Baseload replaced

• Peaking plant requirement increased, but significantly?

• Flexibility - ancillary services provided?

• Impact of storage and interconnection

• Electric vehicles – a fast changing world
Consenting – a better more robust way for all involved?

Source: Haskoning DHV UK Ltd 'Industry Evidence Programme', 2016

Process Evidence

Source: ORJIP
Current context for the future: Europe & 1.5°C

Delivering on the Paris Agreement requires immediate action on three fronts:

- **230 GW offshore wind | 50-80 GW interconnection | 25% dispatchable**

**Spatial planning**
Development of long term spatial planning strategy (internationally coordinated roll-out, benefit to environment, maximise grid integration, at low cost)

**Interconnectivity**
Development of methodology to value grid stability that incentivizes interconnector capacity to maintain operational security

**Flexibility**
Development of 2045 roadmap for flexibility options (storage, demand response, capacity reserves, and other energy sectors)

Source: ECOFYS/Navigant Adopting A Sustainable 2050 Vision For North Seas Infrastructure To Define A Way Forward
Conclusion

Offshore wind is now an affordable technology that will provide a crucial role in the ‘energy transition’, that is happening now, and the pace is picking up

The scale up will require smart and responsible thinking by all stakeholders, the industry needs to do its job well, but also part of an energy system solution

Governments, regulators, stakeholders and multiple industry sectors need to come together for the transition to happen
Offshore Wind Energy
(Maximising Wind Power – how far can the technology go?)

Hugh Yendole
Energy Institute
May 2017

With thanks for Andrew Henderson for various slides

Not to be duplicated without written consent from DONG Energy
Outline of Lecture

Introduction to DONG Energy

Why Offshore Wind Energy?

Historical Perspective: how we arrived here

State-of-the-Art Technology: Burbo Bank Extension

Future Challenges: 3 key issues
DONG Energy at a glance

- Headquarters in Denmark
- 6,200 employees (including Oil & Gas)
- Revenue in 2016 DKK 61.2 bn
- EBITDA in 2016 DKK 19.1 bn
- Phase out the use of coal by 2023

80%* Wind Power
- Develops, constructs, owns and operates offshore wind farms in Denmark, Germany, the Netherlands and the UK.
- Development projects in Taiwan and the USA

4%* Bioenergy & Thermal Power
- Generates and sells power and heat to customers in Denmark and Northwestern Europe

4%* Oil & Gas (discontinued operations)
- Produces oil and gas from fields in Denmark, Norway and the UK

12%* Distribution & Customer Solutions
- Power distribution grid on Zealand and sale of power and gas to customers in Northwestern Europe

* Share of the Group’s capital employed
This is what we do:

London Array Offshore Wind farm

630MW

2 years

EUR 2.2 bn
DONG Energy pioneered the offshore wind industry and is today the global leader

Largest offshore wind player globally today
Global offshore wind capacity
MW

Source: Bloomberg New Energy Finance, March 2017, DONG Energy analysis

1. Statkraft has decided to scale down their activities in offshore wind. Current assets will be built and development projects will be brought forward to allow divestment before FID
2. If a project is executed on behalf of a lead developer managing the construction, then 100% of capacity is allocated to the lead developer. If construction is executed by an integrated joint venture, capacity is allocated in proportion to the JV share
DONG Energy Wind Power geographical footprint

DONG Energy Wind Power overview

Unparalleled experience and track record

21 offshore wind farms in operation
6 offshore wind farms under construction

26 years of experience and track record in the offshore wind sector

1991
2017

3.6 GW Constructed capacity
2,000 Dedicated employees
3.8 GW under construction

7.5 million Europeans with clean electricity
3.9 GW World’s leading operator
14 Partnerships

In operation
Under construction
Under development
Decommissioned
Outline of Lecture

- Introduction to the DONG Energy
- Why Offshore Wind Energy?
- Historical Perspective: how we arrived here
- State-of-the-Art Technology: Burbo Bank Extension
- Future Challenges: 3 key issues
Why the need for Renewables?

- Indigenous/security of supply
- Non-volatile costs
- No GHG
- No geo-political risks
- Inexhaustible
- Safe
- Creates wealth and jobs
- Cost-competitive
- Sustainable

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Brundtland Commission, 1987
....and why in particular Offshore Wind?

- Scale
  - Large capacity power stations
- Controllable
  - within the limits of wind energy in general
  - Auxiliary services
- European Technology Leadership
  - Opportunity for exports

and some of the specific challenges:

- Cost
  - A rapid cost reduction curve can be observed
- Regulatory variation
  - Different regulations mean varied solutions (and therefore costs)
- ‘Easy’ sites (in EU) occupied
- Competition with incumbents
UK Energy Policy merry-go-round

1. Energy Security of supply
   - 25% of UK power stations to close by 2023
   - Increased variable and inflexible capacity
   - Reduced production from UKCS
   - Potential for Shale Gas (fracking)

2. Low Carbon
   - Renewable energy targets (20% energy by 2020)
   - Carbon reduction targets (80% reduction in GHG by 2050, relative to 1990 levels)
   - New nuclear programme
   - Smart technology
   - Jobs opportunity
   - Paris accord: limit to 2degC rise in global temp.

3. Cost to consumer
   - Increasing fuel poverty
   - Increasing cost of levy-funded initiatives
   - Rising consumer prices (increasing domestic tariffs)
   - Brexit – exchange rates change leads to higher consumer prices & other impacts (resources, investment)

Britain is the first country in the world to formally bind itself to cut greenhouse emissions and I strongly believe this will improve our national and economic security. To stay reliant on fossil fuels would mean tying ourselves to increasingly unstable supplies which could endanger our energy security and the Climate Change and Energy Bills mark an important step for both the health of our economy and the health of our nation. It is now vital that we stick to these targets. Rt. Hon. Theresa May, 2008
UK Energy flows 2015

- Transport 24%
- Energy supply 29%
- Residential 13%
- Business 17%
- Agriculture 10%
- Waste management 4%
- Other 4%

Source: DECC/BEIS
UK Energy flows 2015 million tonnes of oil equivalent

Source: DECC/BEIS
Renewable generation represented 24% of electricity production (83TWh)

Offshore Wind provided 21% of the UK’s renewable electricity output (17.4TWh)

Source: DUKEs 2015
The generation mix....

http://www.gridwatchtemplar.co.uk/
Offshore wind in the UK

- 1st windturbines: Blyth 2000
- 1st windfarm: North Hoyle 2003
- 5,339 MW in operation
- 4991 MW under construction
- Further 448 MW with PPAs

- Total of ~10 GW capacity by mid 2020s
Offshore Wind: International Status

Operation:
- UK currently world's largest market
- ~90% of offshore WTGs in Europe

Construction:
- Gradual expansion of number of markets
- Unprecedented worldwide activity
- UK, Germany and China are the main markets
The growth of windpower across the globe

Cumulative global wind power (MW)


Source: GWEC, EWEC, own data
Typical offshore windfarm: Westermost Rough, UK

- Completed July 2015
- 210MW, 35 × Siemens 6.0MW wind turbines, 154 m Ø rotor
- Monopile foundations
- 8km from the shore in 12-28m water
- DONG Energy, Marubeni, GiB
Siemens 6MW - 154

- The SWT-6.0 has a rotor diameter of 154 meters and is designed for the most challenging offshore sites. Swept area of 18,600 m$^2$;
- The rotor starts to spin at wind speeds of 3.5 m/s: the turbine generates optimally at 12-14 m/s;
- The replacement of the traditional main shaft, gearbox and high-speed generator with a low-speed generator has eliminated large moving parts and therefore also the number of components in the nacelle by almost 50 per cent;
- With a tower head mass of roughly 350 tons, the SWT-6.0 is the lightest machine in its class.
Westermost Rough blades
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First Offshore Wind Farm: Vindeby, Denmark

- 1991
- 5MW
- 11 × Bonus (Siemens) wind turbines
- 450kW, 35m Ø Rotor
- 3km from the shore in 2m water

- GBS foundations
- now with DONG Energy
- Currently being decommissioned
First Large Offshore Wind Farm: Horns Rev, Denmark

- 2002
- 160MW
- 80 × Vestas V80 wind turbines
- 2MW, 80m Ø rotor
- 14km from the shore in 6m water
- Monopile foundations
- developed by Elsam (now DONG)
- Still in operation; Vattenfall
Simplified offshore wind farm set-up
Mini quiz: what's happening here?
### Outline of Lecture

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State of the art: Burbo Bank Extension

Key data for the project

Development Start: March 2010
Construction start: March 2015
Offshore start: April 2016
WTG installation start: July 2016
Installation completion: December 2016
Array: Optimised array (40 km²)
Turbines: 32 x MVOW 8.0-164(258 MW)
Electrical: 33/220/400 kV step-up
Water Depths: 4 – 17 m LAT
Average wind speed: 9.0 m/s
Burbo Bank Extension (under construction)
Burbo Bank Extension is a ground breaking project....
Burbo Bank Extension (complete!)
### Outline of Lecture

- **Introduction to the Presenters**
- **Why Offshore Wind Energy?**
- **Historical Perspective: how we arrived at today**
- **State-of-the-Art Technology: Burbo Bank Extension**
- **Future Challenges: 3 key issues**
Key challenges for offshore wind

1. Local Content
2. Supply chain bottlenecks
3. Cost of Electricity
Challenge 1: Improving UK local content

Local presence and content is a significant success factor in the supply chain

- **Improving infrastructure:** supporting £50m investment in Belfast Harbour

- **Creating jobs:** West of Duddon Sands: estimated to create ~300 UK jobs during 24 years

- **Building a UK skills base:** Investment in education and training to create the skilled labour pool.

- **Export opportunities:** UK businesses selling expertise abroad, post Brexit.
Belfast Harbour
### Challenge 2: Top four current supply chain bottlenecks in Europe

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<th>Category</th>
<th>Description</th>
<th>Supply chain risk</th>
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| **Subsea export cables**         | ▪ Few players – all abroad  
▪ Timescales to increase capacity are tight  
▪ A few new entrants foreseen                                                                                                                  | High              |
| **DC substation electrical systems** | ▪ New technology  
▪ Few suppliers  
▪ Limited potential for new entrants                                                                                                              | High              |
| **Offshore wind turbines**       | ▪ Sufficient capacity of 6MW+ WTGs, but little competition and many recent mergers.  
▪ Few 6MW+ WTGs in development  
▪ Investment required in manufacturing facilities for larger WTGs.                                                                                   | High              |
| **Foundation installation**      | ▪ Sufficient number of vessels, but many are not efficient for installing jacket foundations  
▪ Few next generation concepts in development, - little consensus on optimal solution                                                                 | Medium            |
Challenge 3: The cost of energy target will be achieved through improvements within several areas

Indexed LCoE (illustrative)

-35-40%

100

LCoE (for 2017 FID)  Radical CoE initiatives  Continuous improvement  Wind resources  Water depth & distance to shore  LCoE (for 2024 FID)

10

60

60-70

100
At the forefront of making the industry cost competitive

Multiple levers to drive down cost in offshore wind

1. **Scale**
   - Turbines and rotor size
   - Sites
   - Vessel size
   - Cable capacity

2. **Innovation**
   - Foundation design (e.g. monopiles)
   - Electrical

3. **Industrialisation**
   - Transition from single supply to multiple global suppliers

Rapid technological development
Wind turbine rotor diameter, year of commissioning

- Boeing 747, 76m
- 80m in 2002
- 90m in 2005
- 107m in 2007
- 120m in 2011
- 154m in 2014
- 164m in 2017
- 180m in 2020

1. Final investment decision (FID). All LCoE estimates assume a WACC of 10%.
2. For UK project with FID taken in 2020, corresponding to CoD in 2023
Wind Turbines – Siemens 3.6-120 with blade improvements
Standardisation: Simplified offshore wind farm set-up
Acknowledgement to Matthew Knight, Siemens
Standardisation: offshore substations

Standardised modules
Example: Offshore substation standardised at c.330 MW

Applied over several projects

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<th>Installation</th>
<th># topsides</th>
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<td>Burbo B Ext.</td>
<td>2016</td>
<td></td>
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<tr>
<td>Race Bank</td>
<td>2017</td>
<td></td>
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<tr>
<td>Walney Ext.</td>
<td>2018</td>
<td></td>
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Main benefits
1. Majority of design work performed only once
2. Systematic design for cost approach
3. Convoy procurement (scale, competition)
4. Earlier certification, reduced throughput time.
Mini quiz: ideas/factors to reduce the cost of offshore wind further?

- Revolutionary
- Evolutionary
- Regulatory
- ?
Where to find out more:

- **Windflow**: [https://earth.nullschool.net/#current/wind/surface/level/](https://earth.nullschool.net/#current/wind/surface/level/)
- **4C Offshore**
  - database of windfarms, windturbines, vessels, ports etc. etc.: [http://www.4coffshore.com/windfarms/](http://www.4coffshore.com/windfarms/)
  - global interactive GIS map: [http://www.4coffshore.com/offshorewind/](http://www.4coffshore.com/offshorewind/)
- **IEA / GWEC /EWEA** and RenewablesUK reports, including:
  - IEA annual report: [https://www.ieawind.org/annual_reports.html](https://www.ieawind.org/annual_reports.html)
  - EWEA offshore wind status reports: [https://windeurope.org/about-wind/](https://windeurope.org/about-wind/)
- **European Wind contribution**: [https://windeurope.org/about-wind/daily-wind/#](https://windeurope.org/about-wind/daily-wind/#)
- **Gridwatch**: [http://www.gridwatch.templar.co.uk/](http://www.gridwatch.templar.co.uk/)
- **Design Standards and Guidelines** (detailed technical information)
  - **DNV - Germanischer Lloyd**: [https://rules.dnvgl.com/ServiceDocuments/dnvgl/#!/home](https://rules.dnvgl.com/ServiceDocuments/dnvgl/#!/home)
- **Offshore wind works**: [http://offshorewind.works/](http://offshorewind.works/)
- **DONG Energy Windpower**

Source: [https://earth.nullschool.net](https://earth.nullschool.net)
Sunrise or sunset?
The future? Block Island, USA

and thank you for your attention

For more information:
www.DONGEnergy.co.uk