

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 ...?
- 5) Conclusions

# Who we are

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

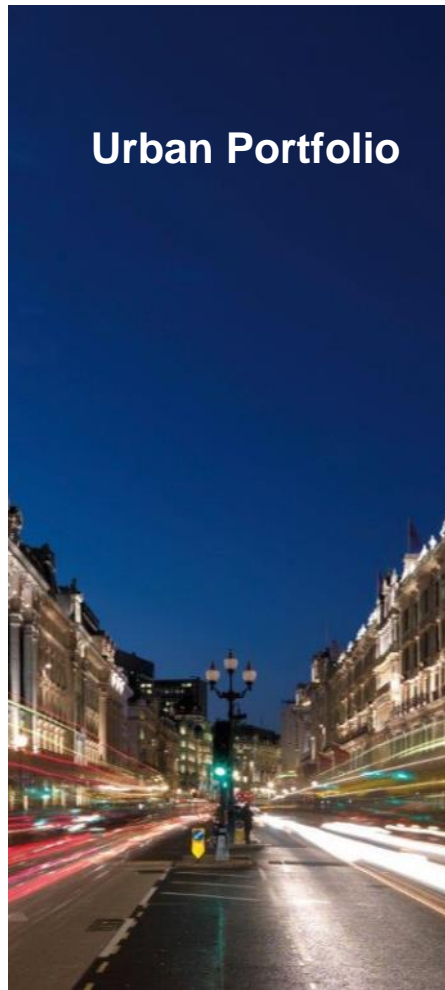


Net profit in 2015/16  
£304.1 million



Our capital value is  
£12.9 billion

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<sub>2</sub> Storage



Minerals



Wave and Tidal energy



Cables & pipelines



Offshore Wind energy

# Does not include...



Fisheries



Water column



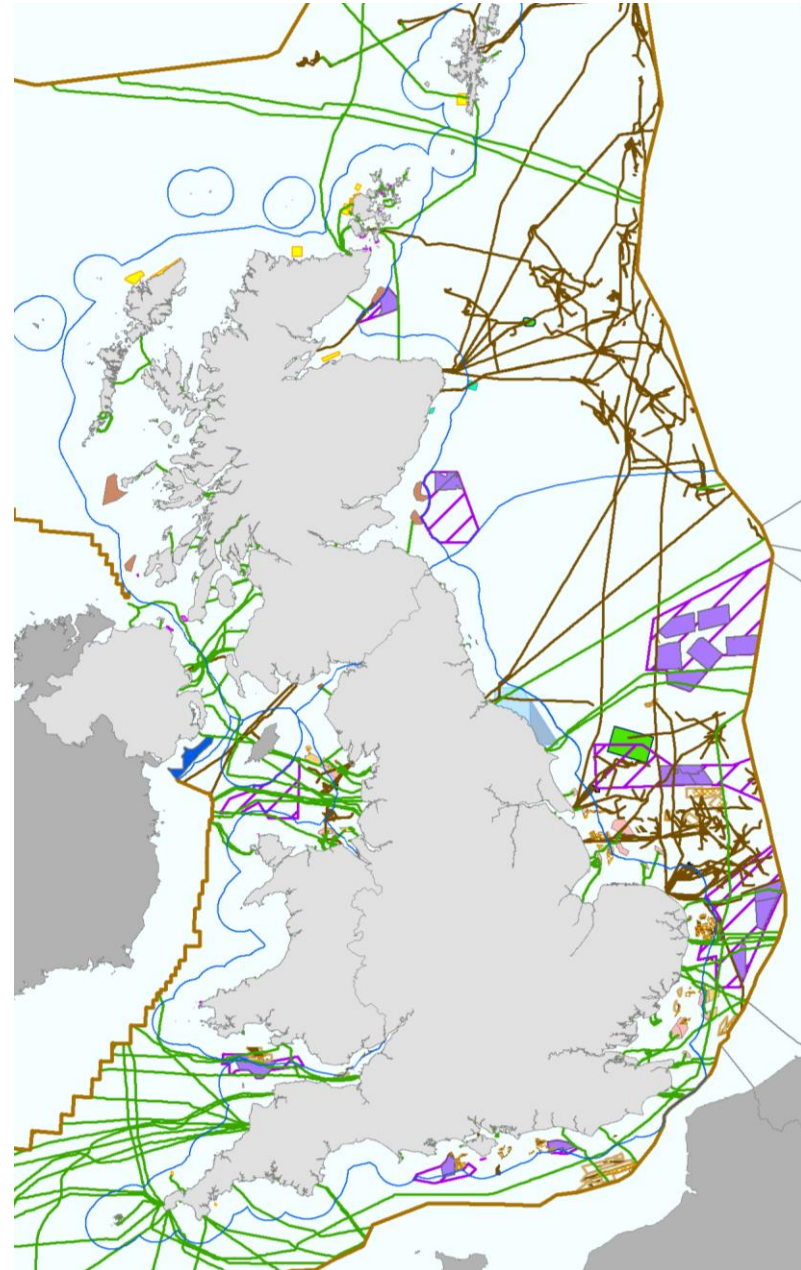
Hydrocarbons



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)
- The Renewable Energy Zone – REZ (Energy Act 2004)
- Gas Importation and Storage Zone - GISZ (Energy Act 2008)

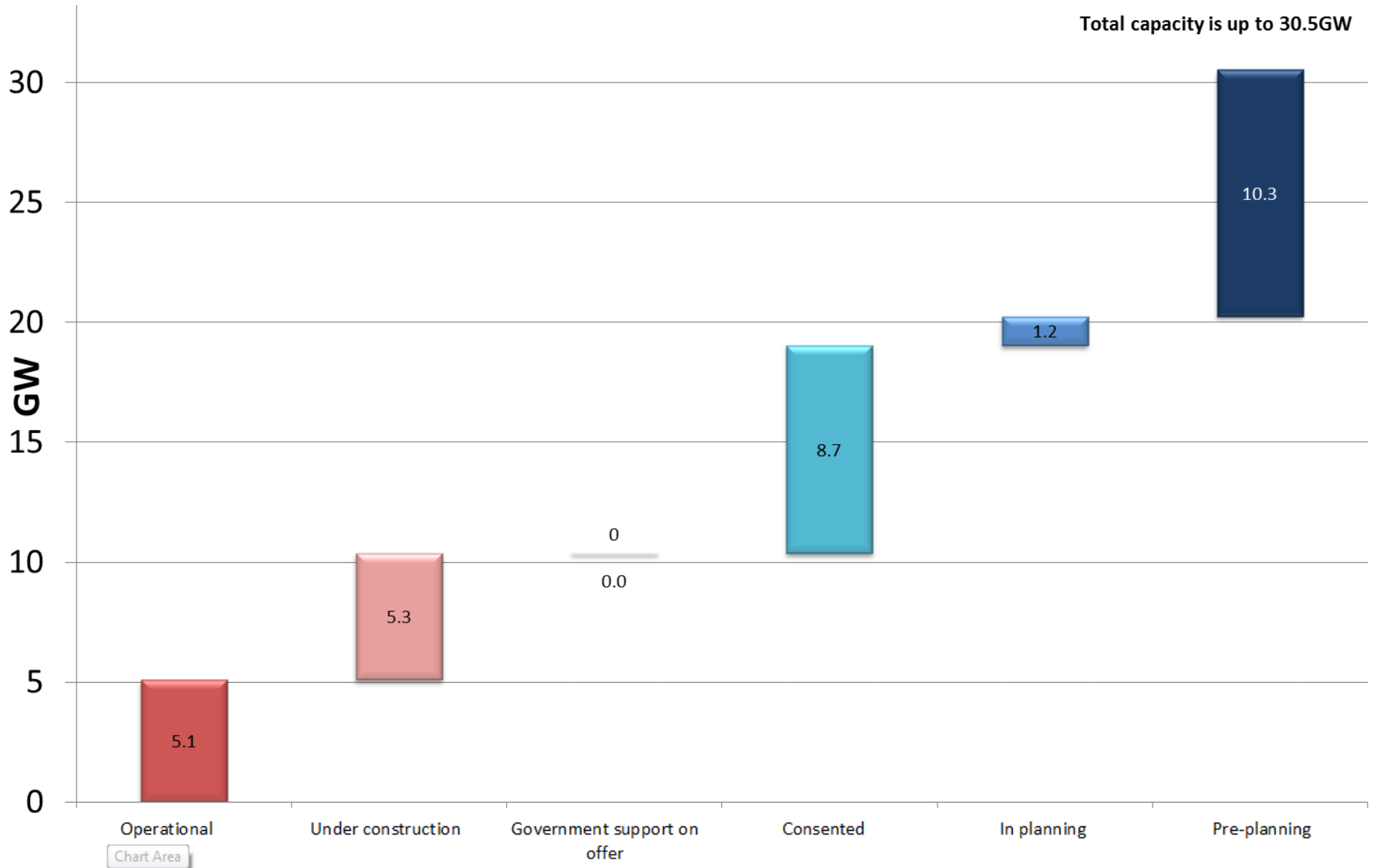


# UK Offshore Wind Portfolio





# UK Offshore Wind - January 2017

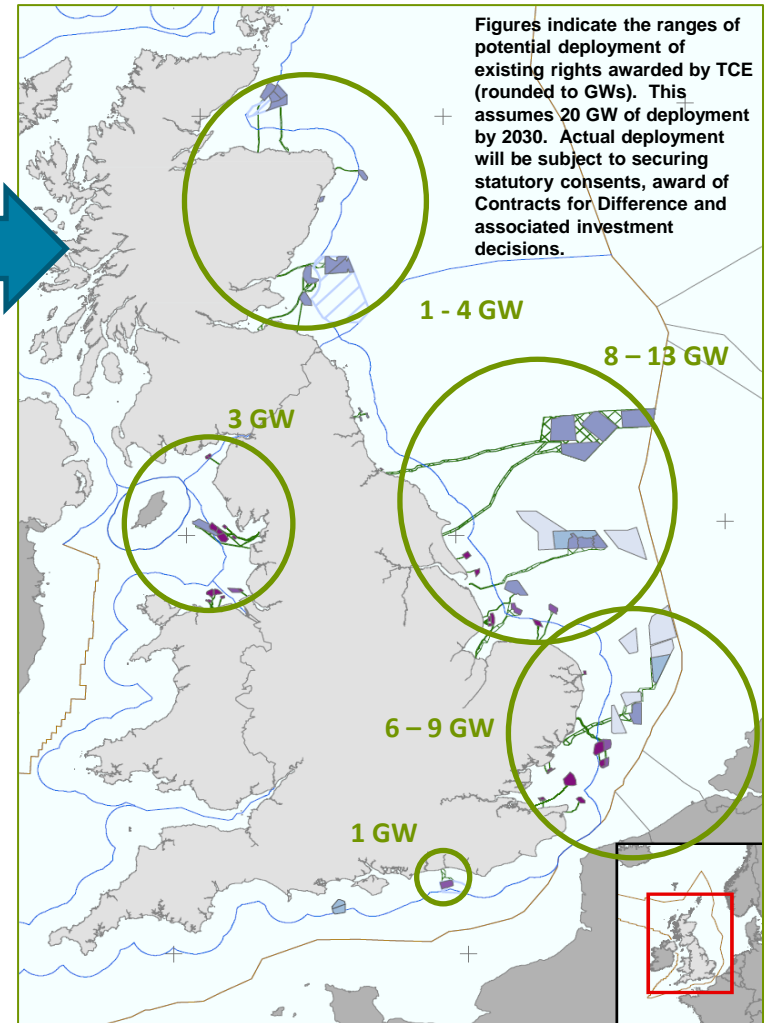
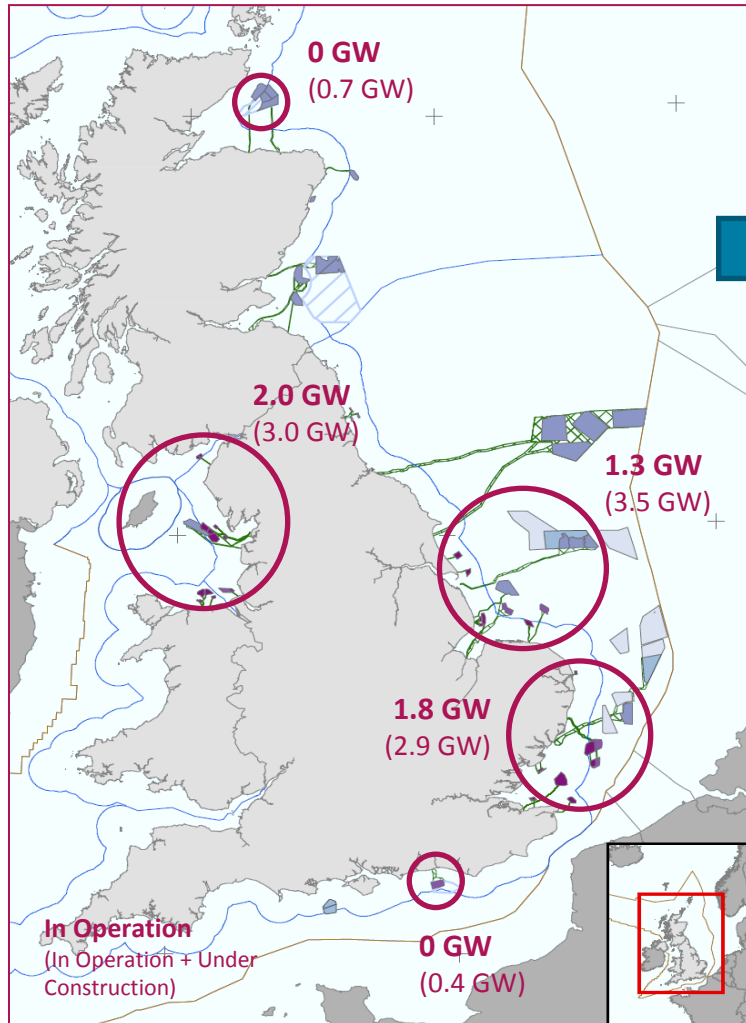


# OSW Spatial distribution 2016 – 2030s

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

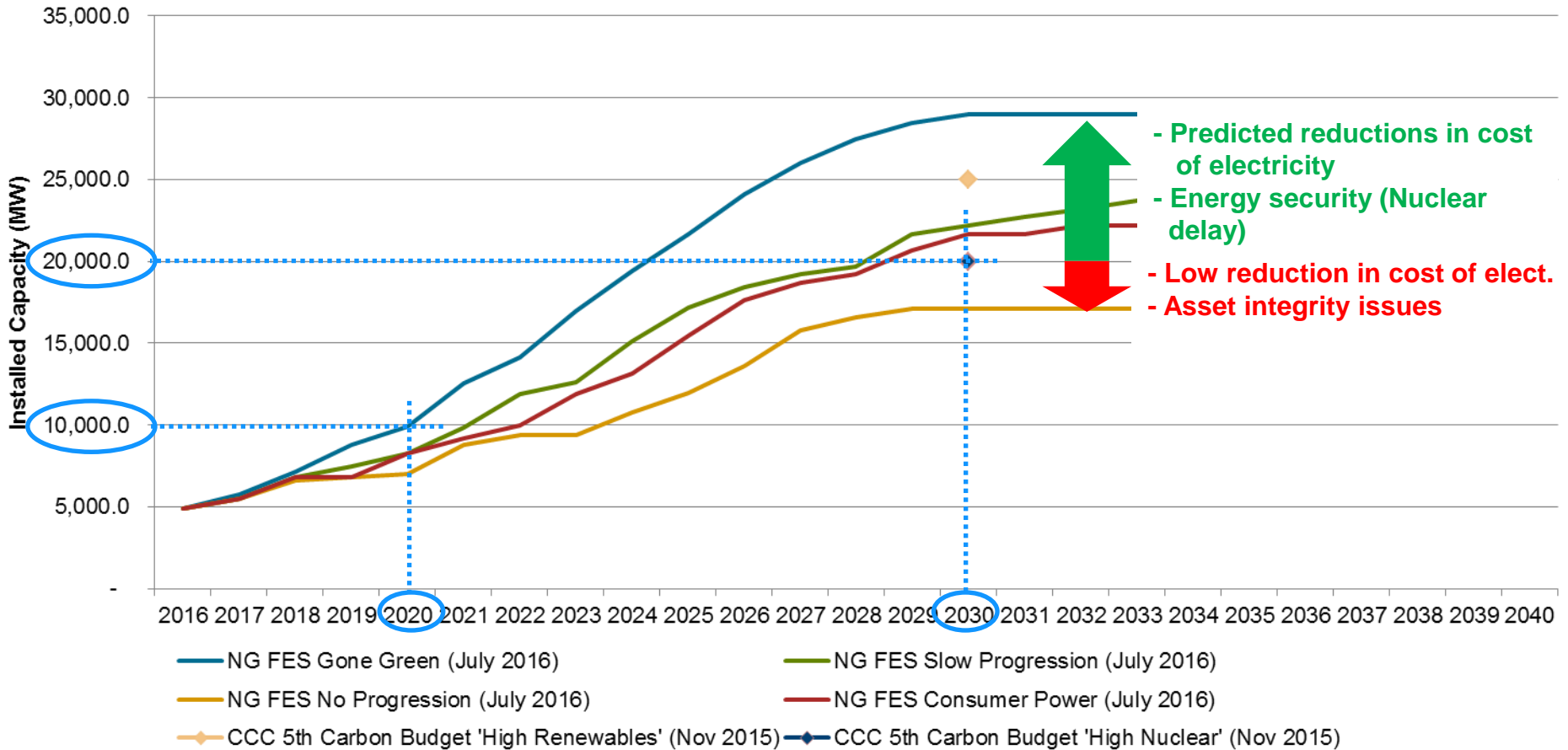
*“If [the necessary cost reduction] happens we could support up to 10GW of new offshore wind projects in the 2020s.”*

Amber Rudd – DECC Secretary of State, November 2015



# Future demand for offshore wind generation

## Offshore Wind Scenarios to 2040

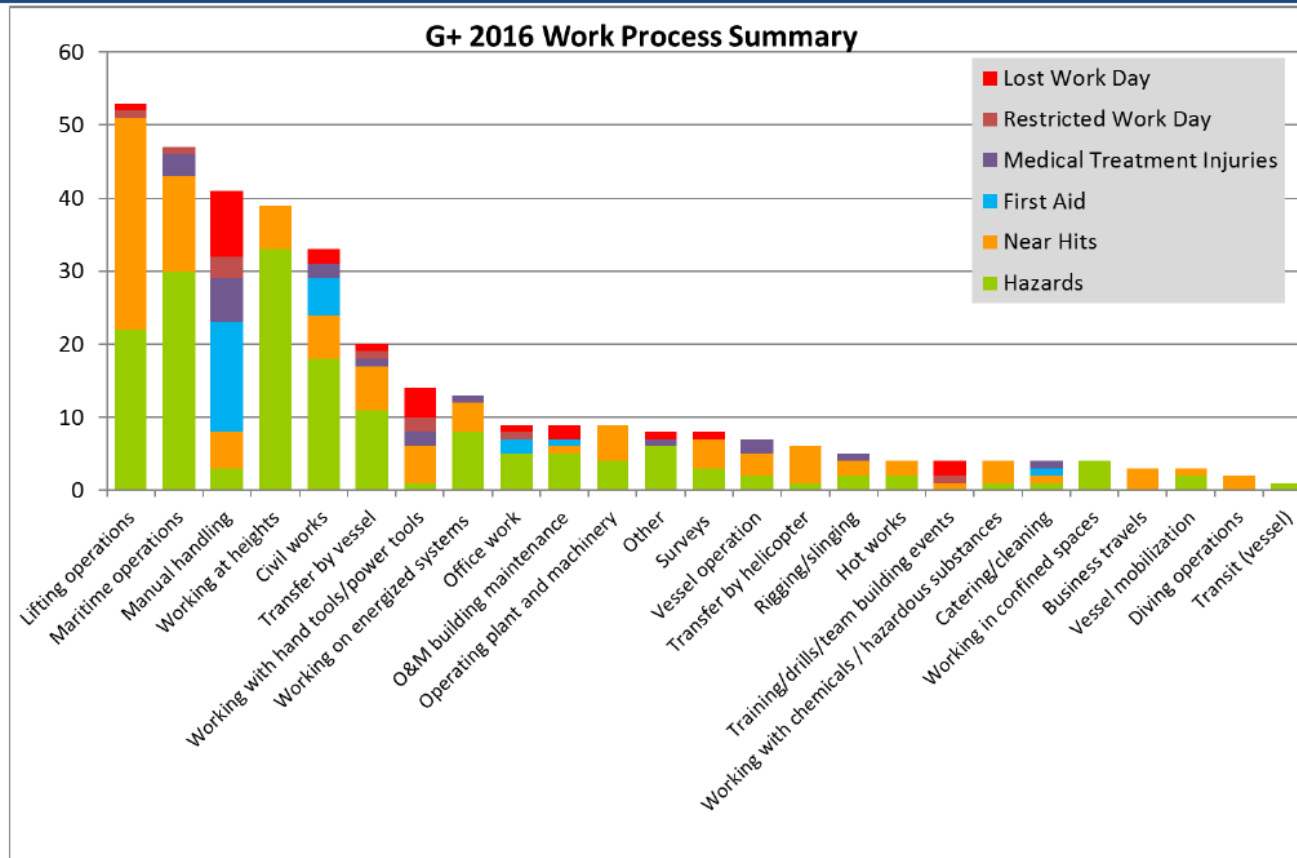


A mature industry ...?



# Health & Safety – G+

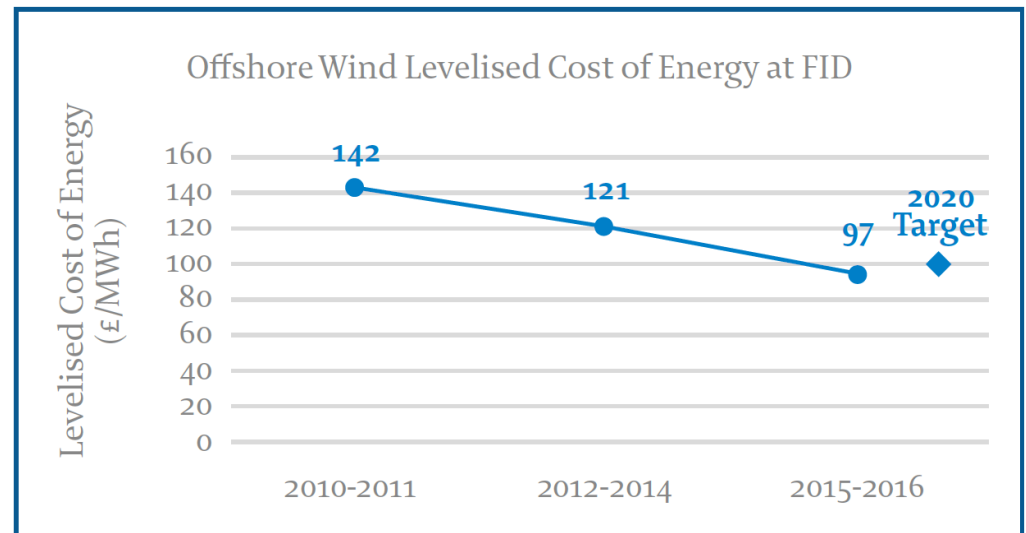
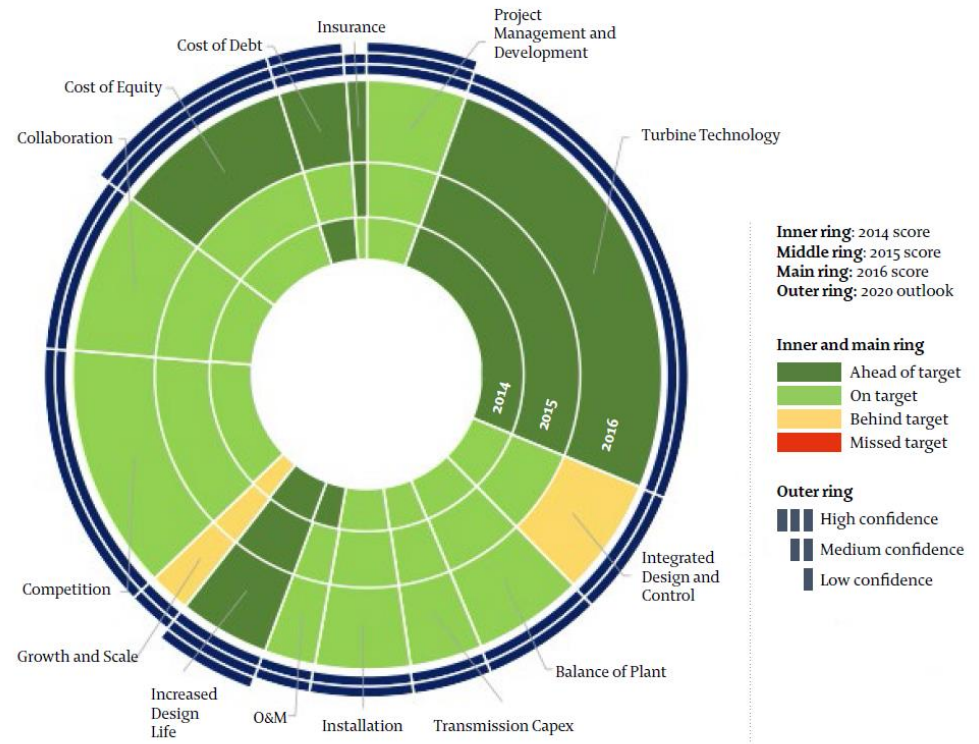
## What is the 2016 data showing?



[gplusoffshorewind.com](http://gplusoffshorewind.com)

# 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



**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



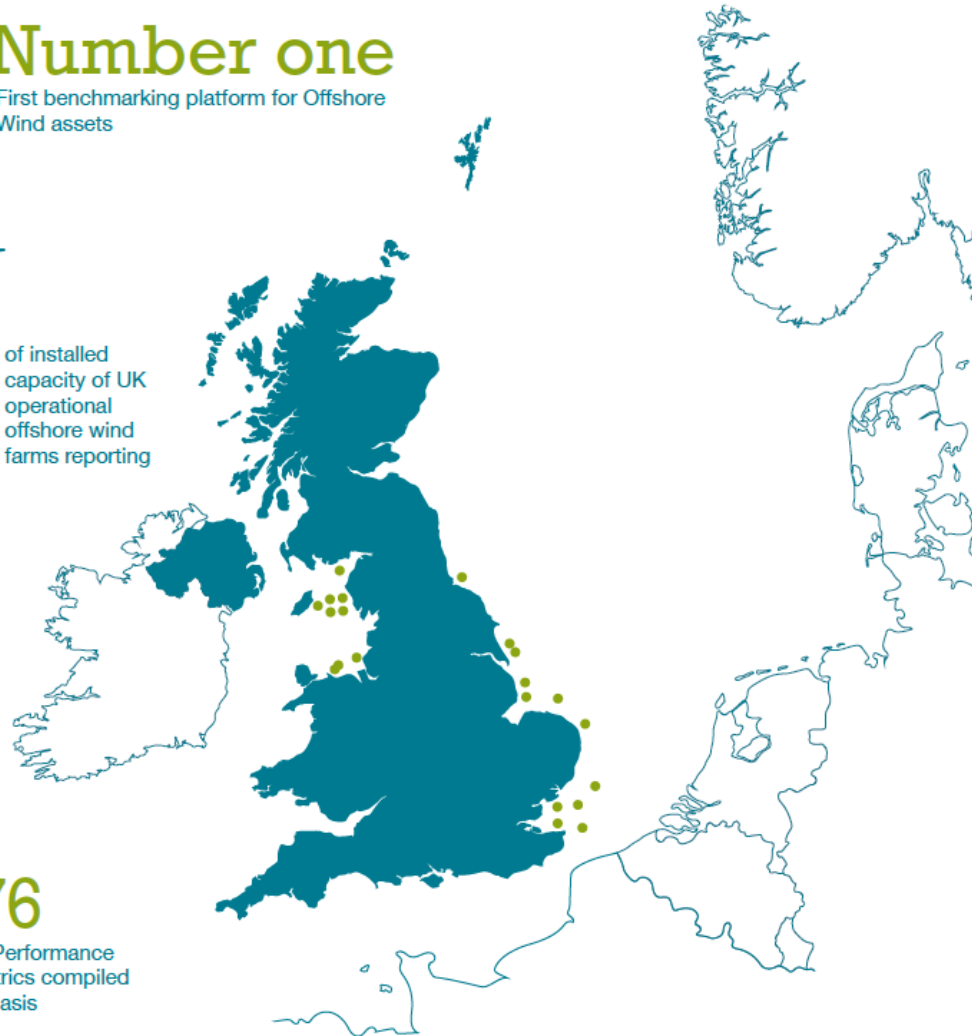
**19,465**

Data points reported  
in year



**76**

Unique Key Performance  
Indicator metrics compiled  
on monthly basis



### SPARTA members

**centrica**

**DONG  
enerqu**



**e-on**



**SCOTTISHPOWER**

**SSE**

**Statkraft**



**VATTENFALL**

### Sponsoring organisations

**THE CROWN  
ESTATE**

**cATAPULT**  
Offshore Renewable Energy

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.*

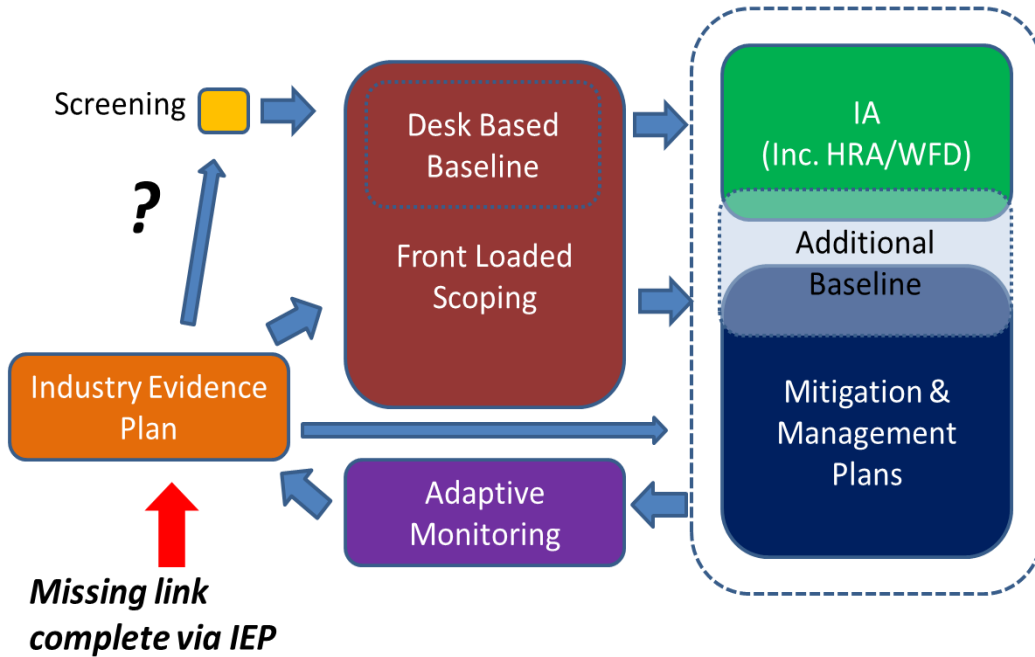
*"The existing levy control framework has helped to control the costs of low carbon subsidies in recent years, and will be replaced by a new set of controls. These will be set out later in the year."*

**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 →

Offshore Wind  
**orjip**  
 working to accelerate offshore consenting



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)



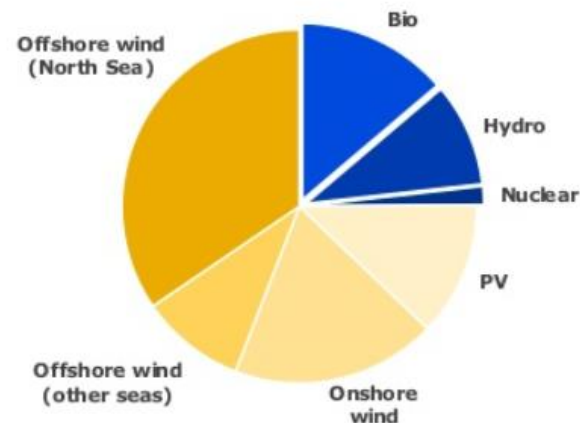
## Interconnectivity

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)



## 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

**DONG**  
energy

*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**

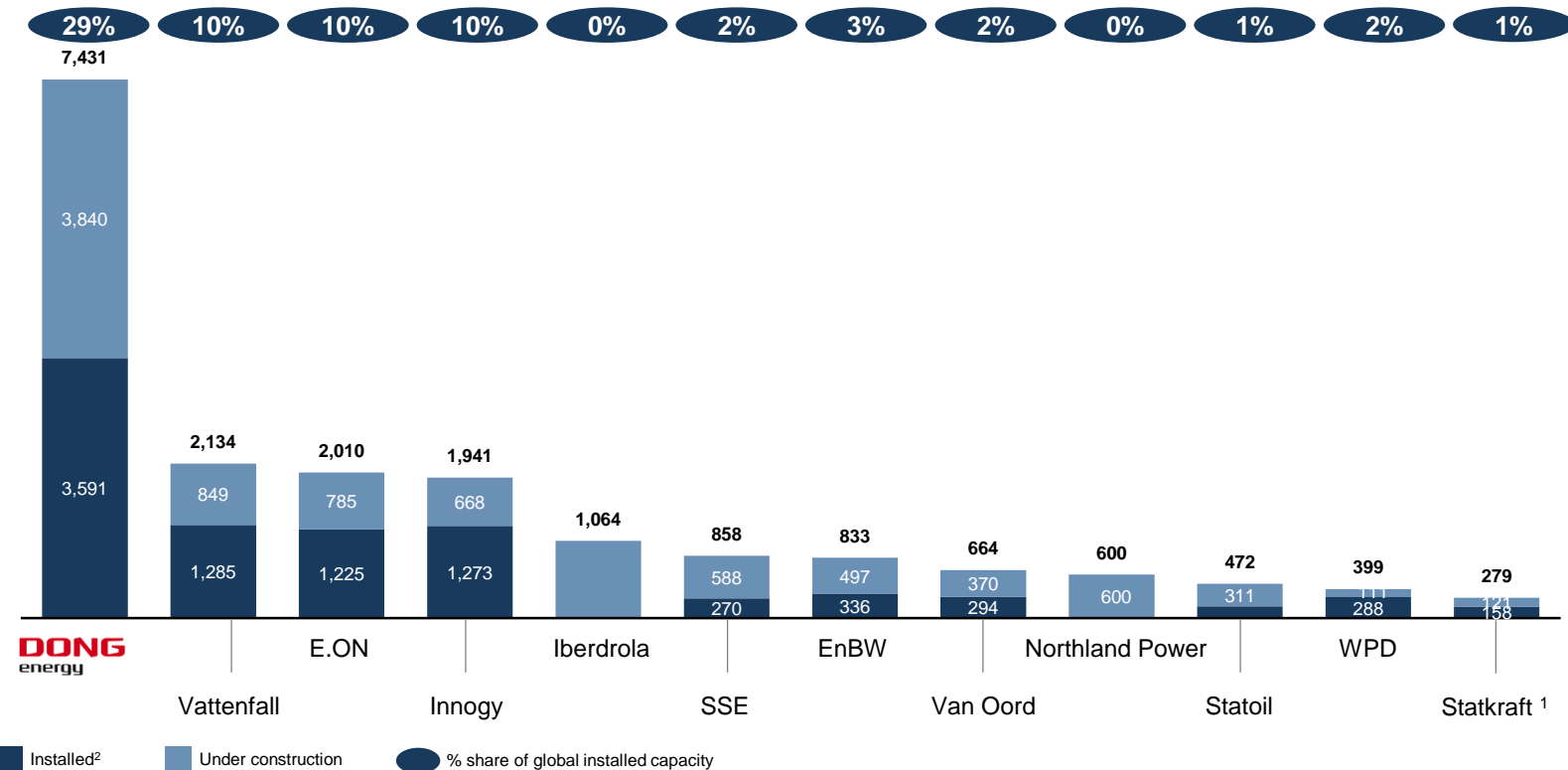
**EUR 2.2 bn**

**DONG**  
energy

# DONG Energy pioneered the offshore wind industry and is today the global leader

## Largest offshore wind player globally today

Global offshore wind capacity  
MW

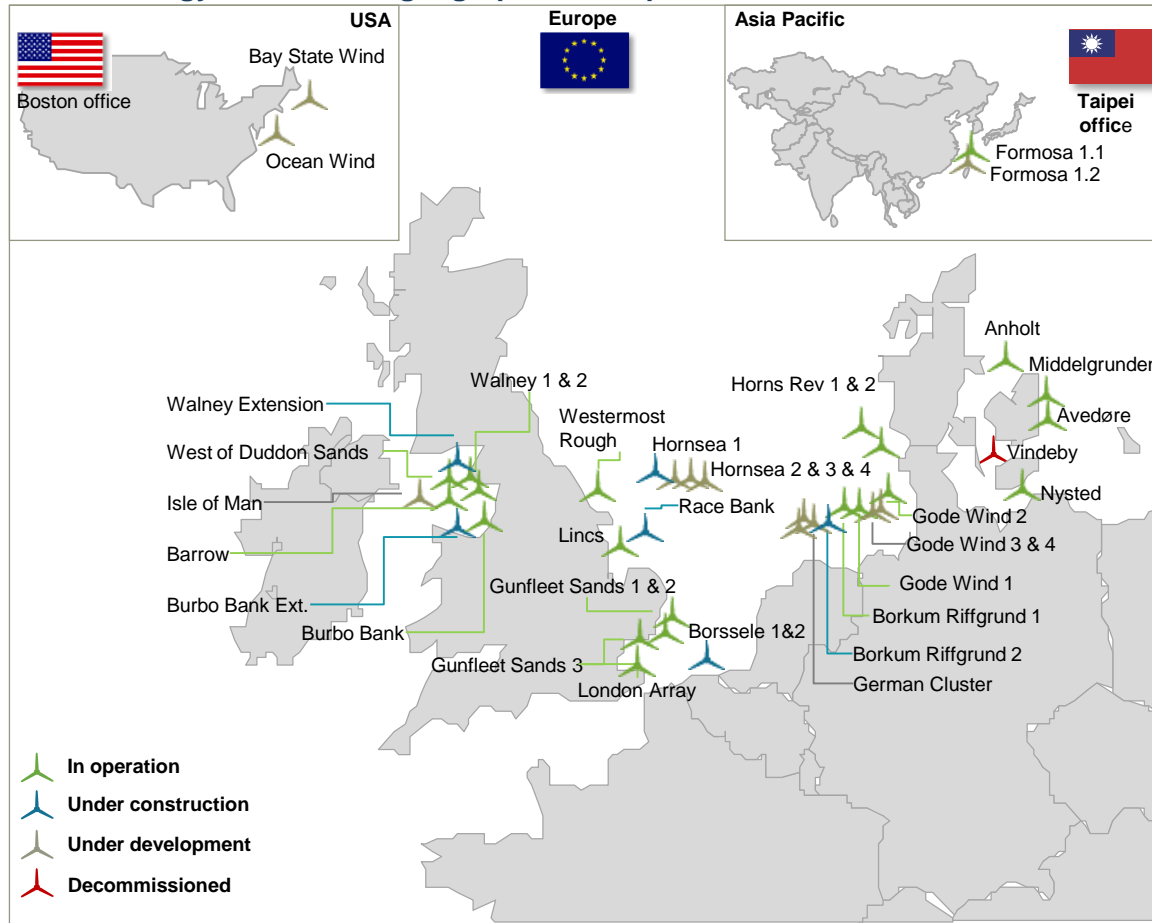


Source: Bloomberg New Energy Finance, March 2017, DONG Energy analysis

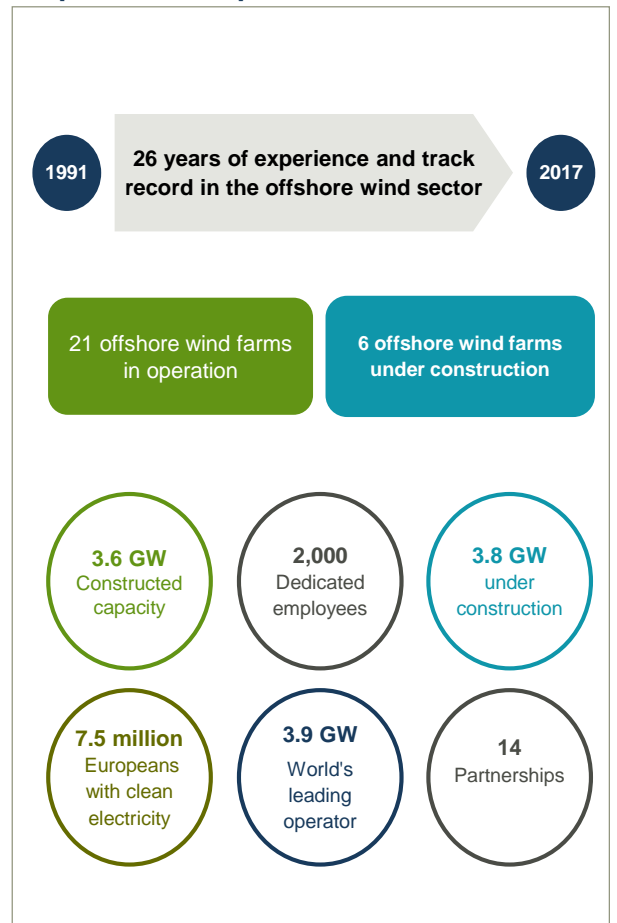
1. Statkraft has decided to scale down their activities in offshore wind. Current assets will be built and development projects will be brought forward to allow divestment before FID
2. If a project is executed on behalf of a lead developer managing the construction, then 100% of capacity is allocated 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 overview

## DONG Energy Wind Power geographical footprint



## Unparalleled experience and track record



# 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:

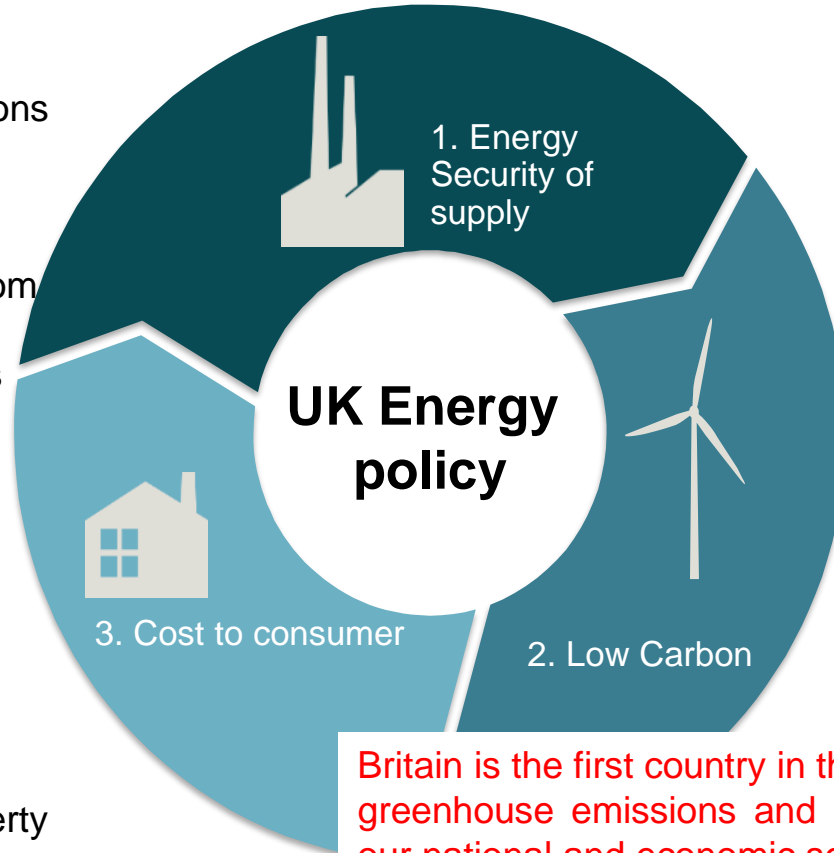
- Cost
  - A rapid cost reduction curve can be observed
- Regulatory variation
  - Different regulations mean varied solutions (and therefore costs)
- 'Easy' sites (in EU) occupied
- Competition with incumbents



# UK Energy Policy merry-go-round

1

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



2

- 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

- 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)

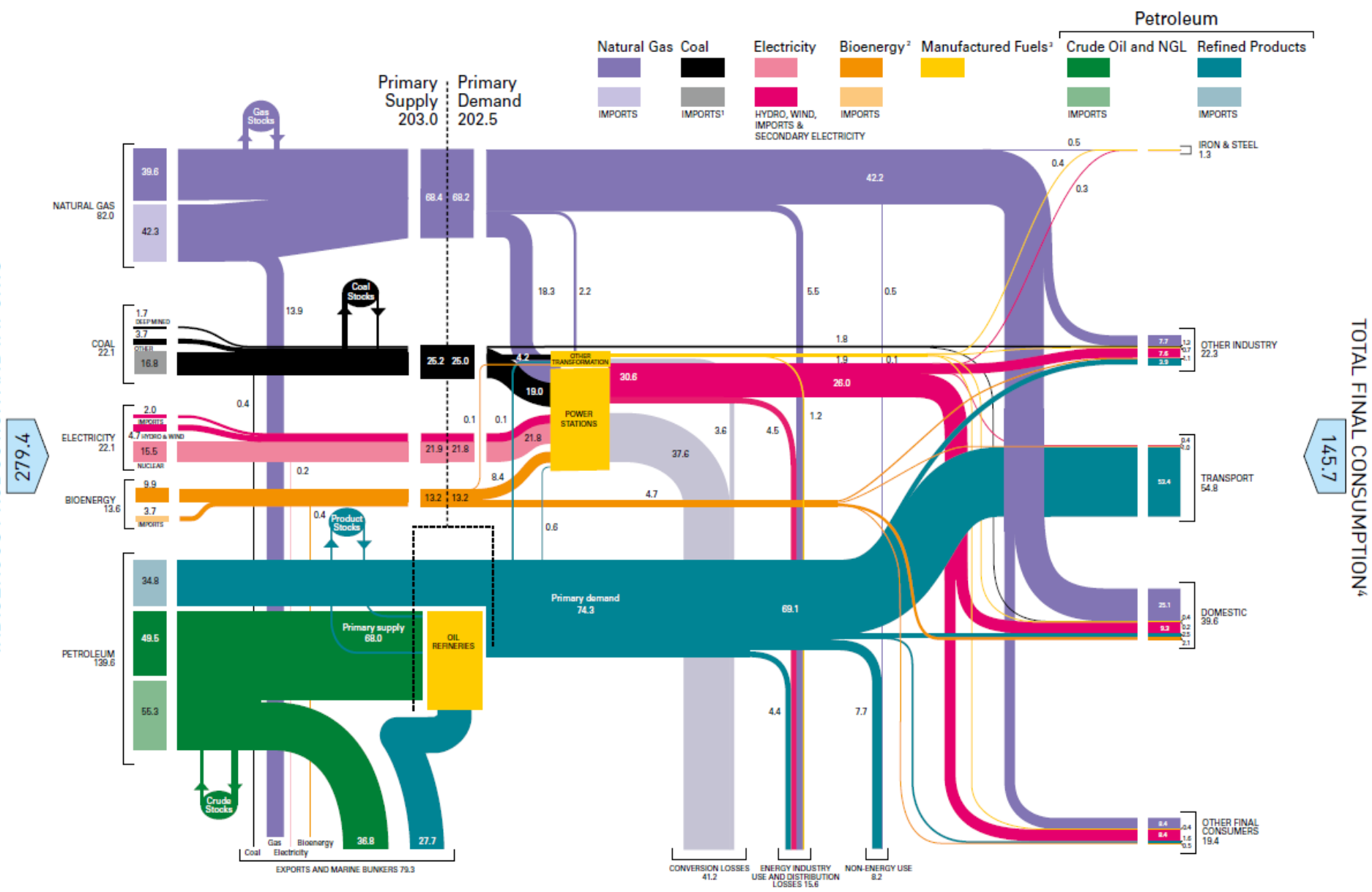
Britain is the first country in the world to formally bind itself to cut greenhouse emissions and I strongly believe this will improve our national and economic security. To stay reliant on fossil fuels would mean tying ourselves to increasingly unstable supplies which could endanger our energy security 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**





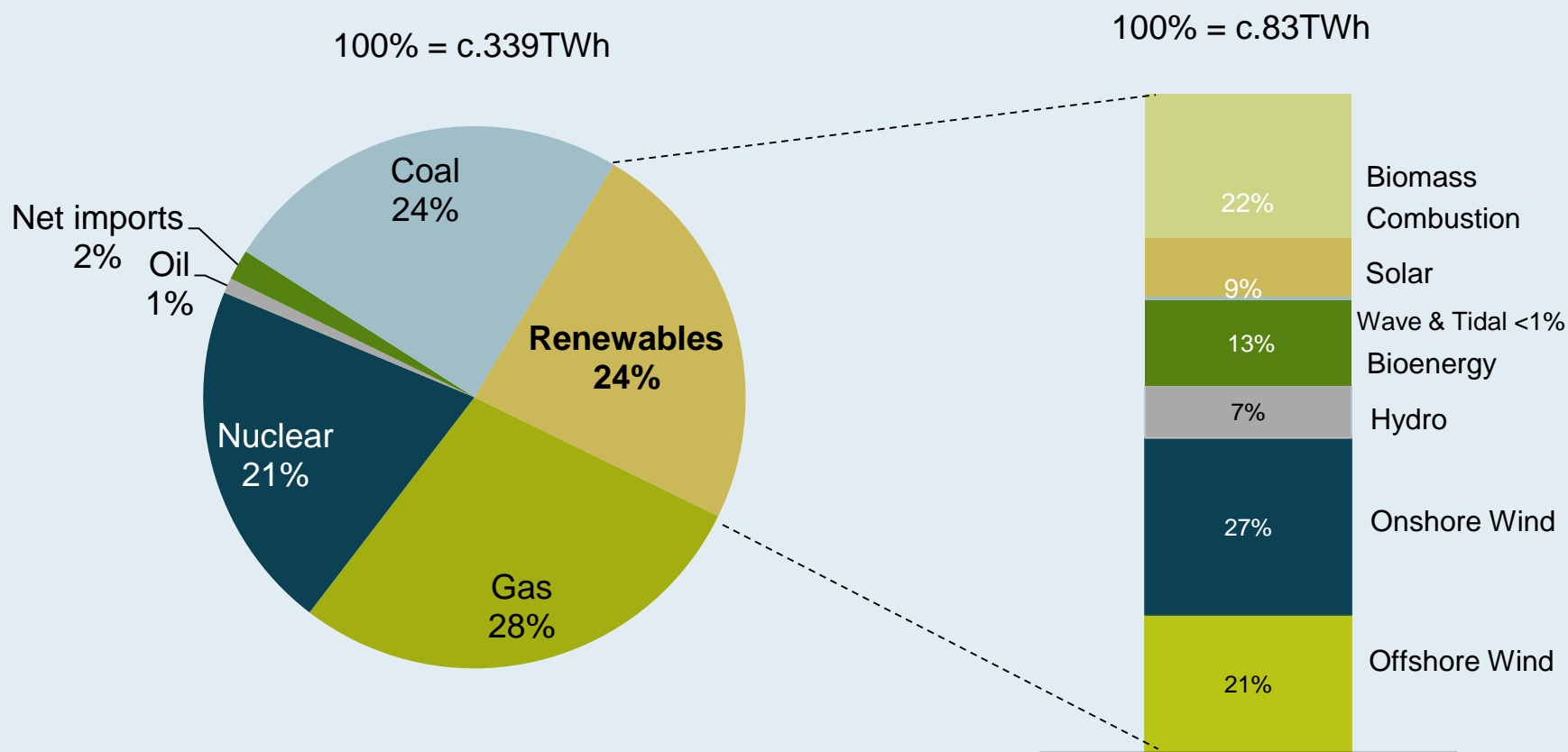
# UK Energy flows 2015 million tonnes of oil equivalent

INDIGENOUS PRODUCTION AND IMPORTS



# UK Generation mix 2015

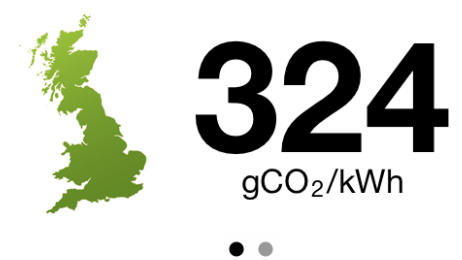
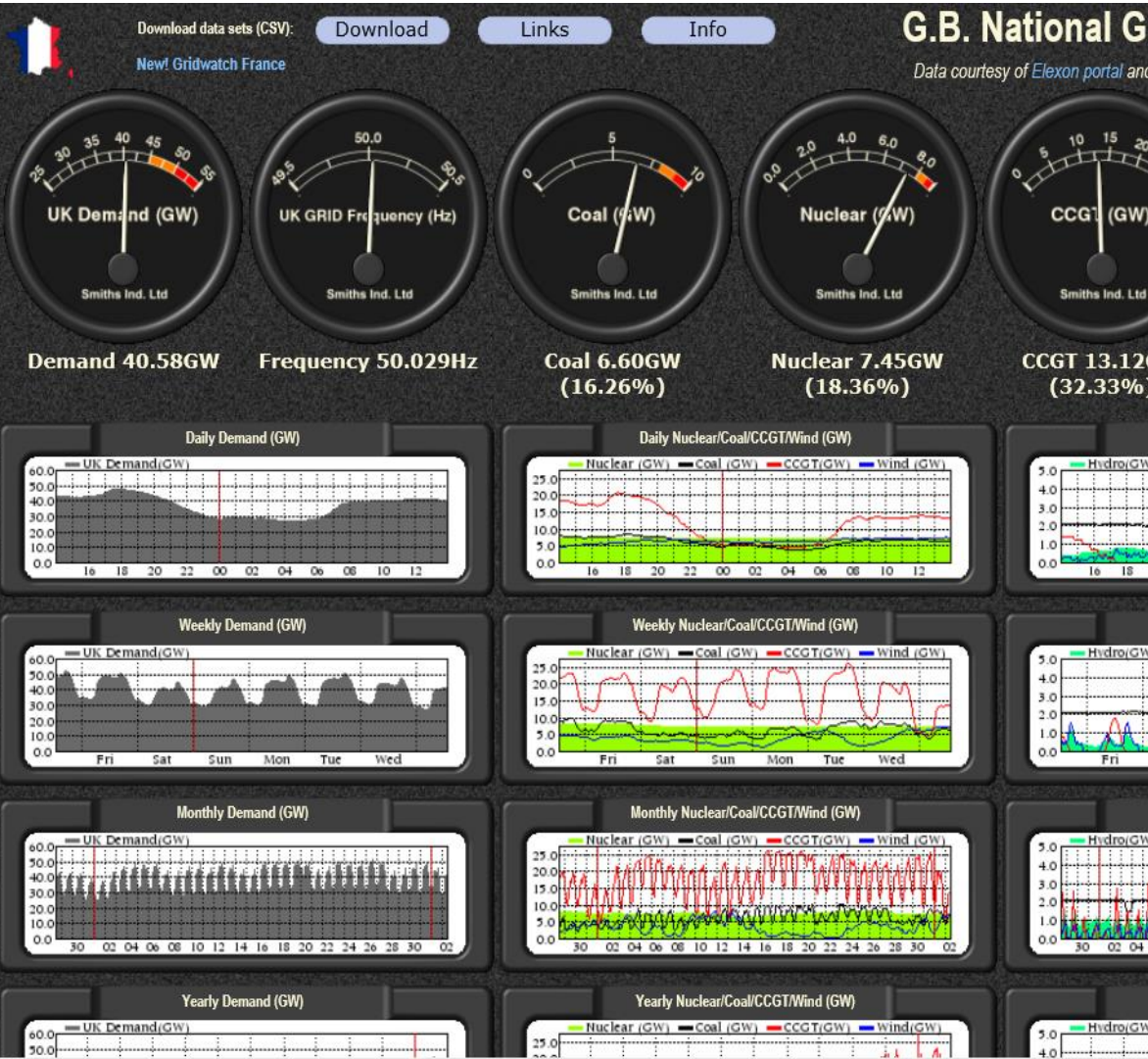
Renewable generation represented 24% of electricity production (83TWh)



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

# The generation mix....

## UK Grid Carbon Intensity



	Gas	16400 MW (35.9%)
	Wind	8200 MW (17.8%)
	Nuclear	7400 MW (16.3%)
	Coal	7300 MW (15.9%)
	Other	2000 MW (4.5%)
	Storage	1500 MW (3.2%)
	Dutch IC	1000 MW (2.2%)
	French IC	1000 MW (2.2%)
	Hydro	940 MW (2.1%)

Updated 02/02/2017 17:35 UTC

# Offshore wind in the UK

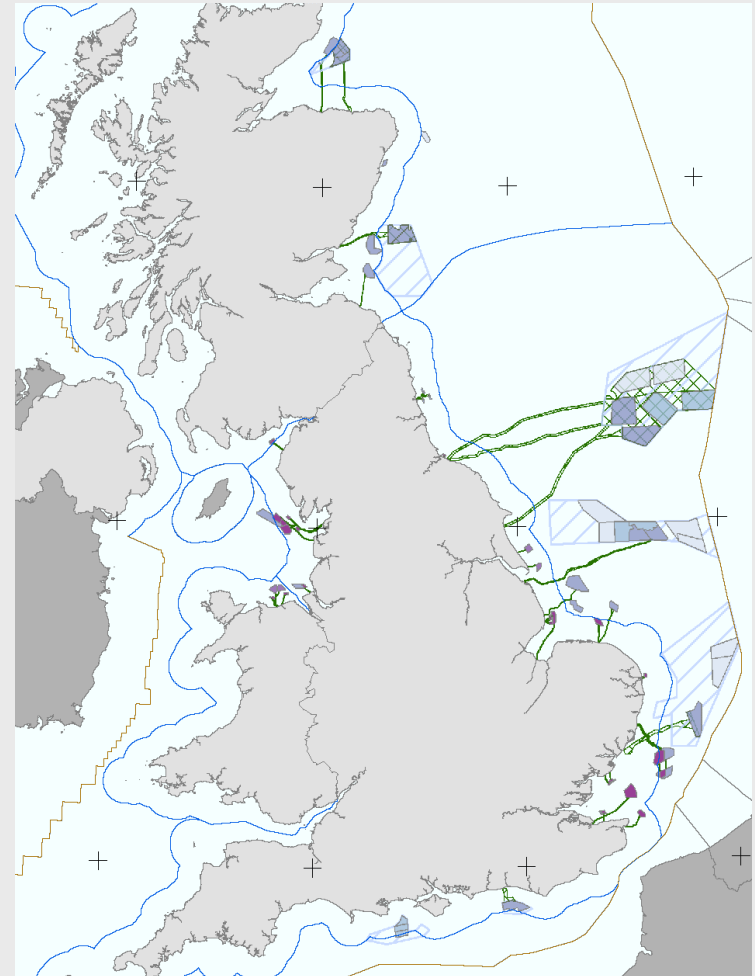
- 1<sup>st</sup> windturbines: Blyth 2000
- 1<sup>st</sup> windfarm: North Hoyle 2003
- 5,339 MW in operation
- 4991 MW under construction
- Further 448 MW with PPAs
- Total of ~10 GW capacity by mid 2020s

## Offshore Wind Activity

- Operational Wind Farm
- Under Construction Wind Farm
- Consented Wind Farm
- In Planning Wind Farm
- Pre-planning Wind Farm
- Area of Search
- Wind Farm Export Cable Agreements

## Base Map

- Territorial Waters Limit
- UK Continental Shelf
- International Waters
- United Kingdom
- Europe

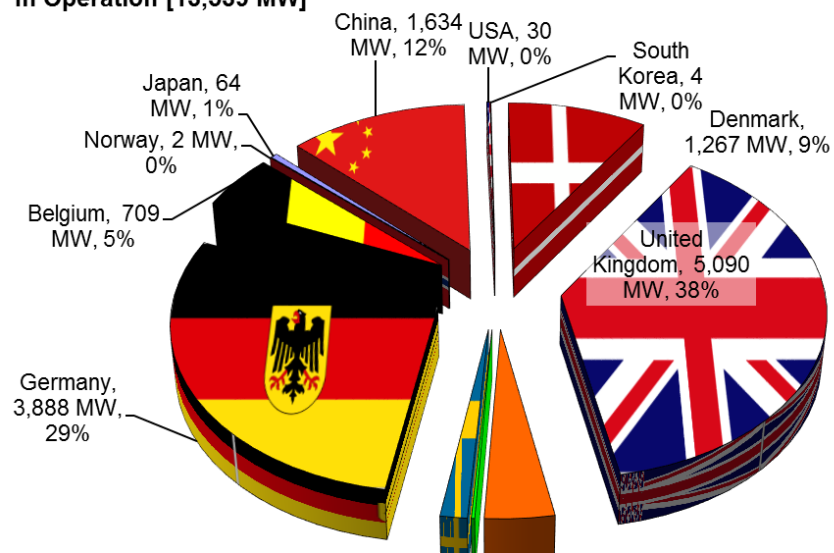


# Offshore Wind: International Status

## Operation:

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

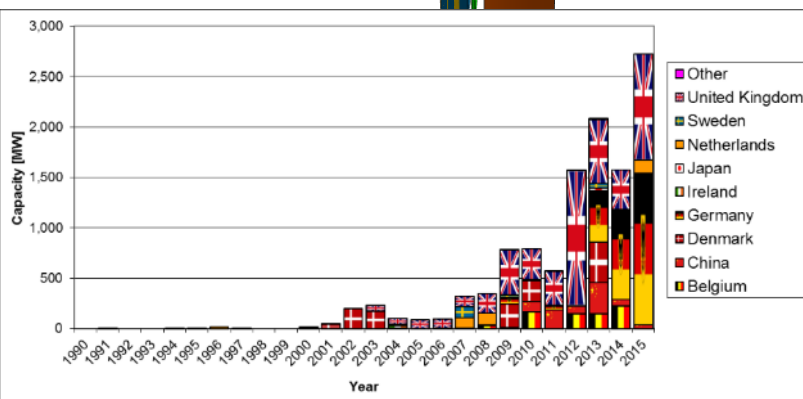
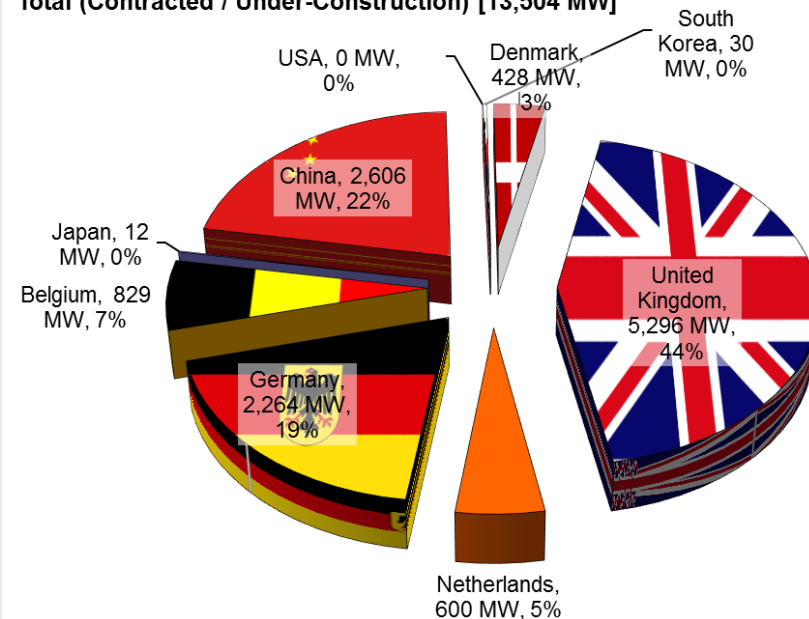
In Operation [13,539 MW]



## Construction:

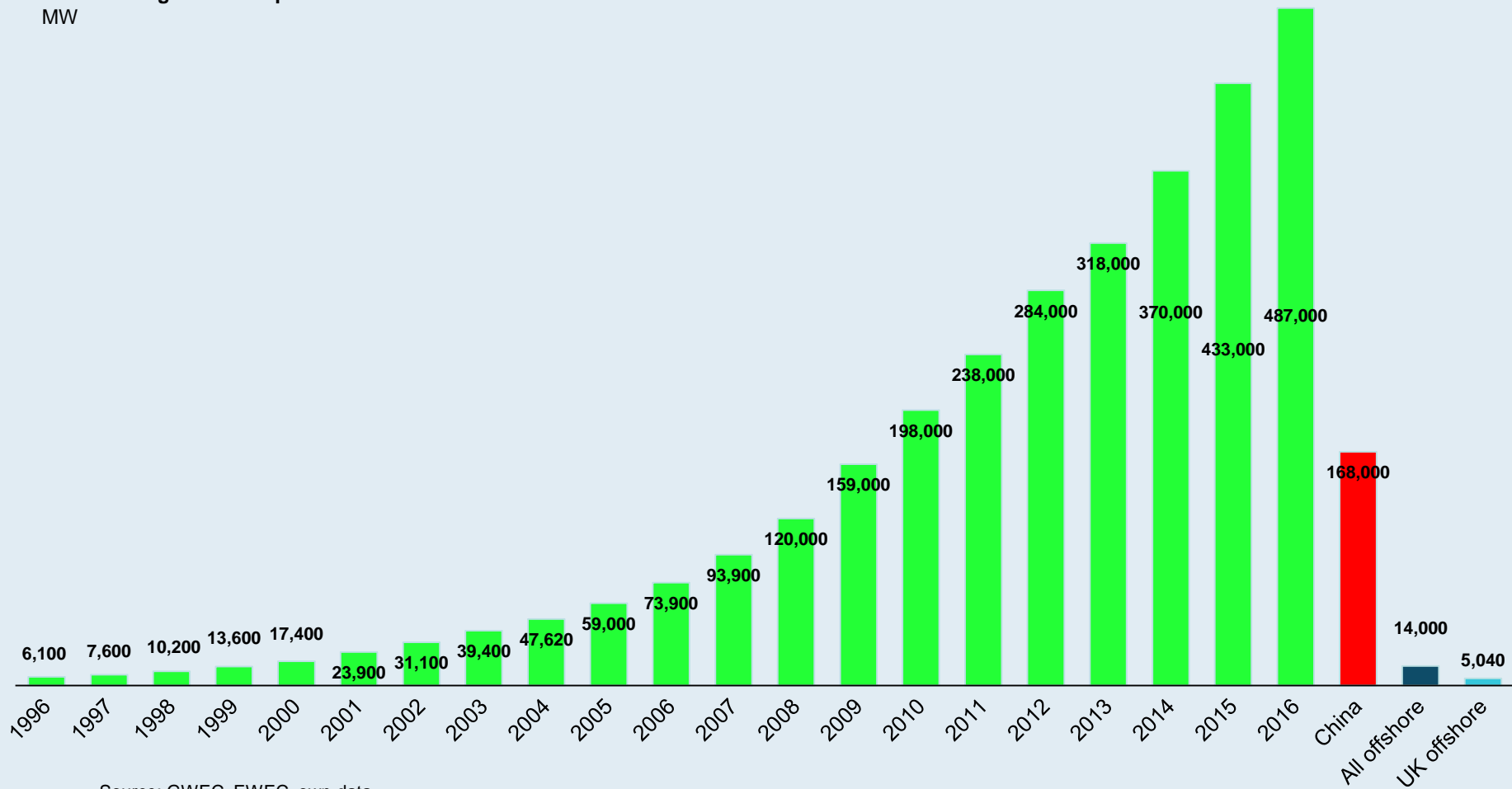
- Gradual expansion of number of markets
- Unprecedented worldwide activity
- UK, Germany and China are the main markets

Total (Contracted / Under-Construction) [13,504 MW]



# 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

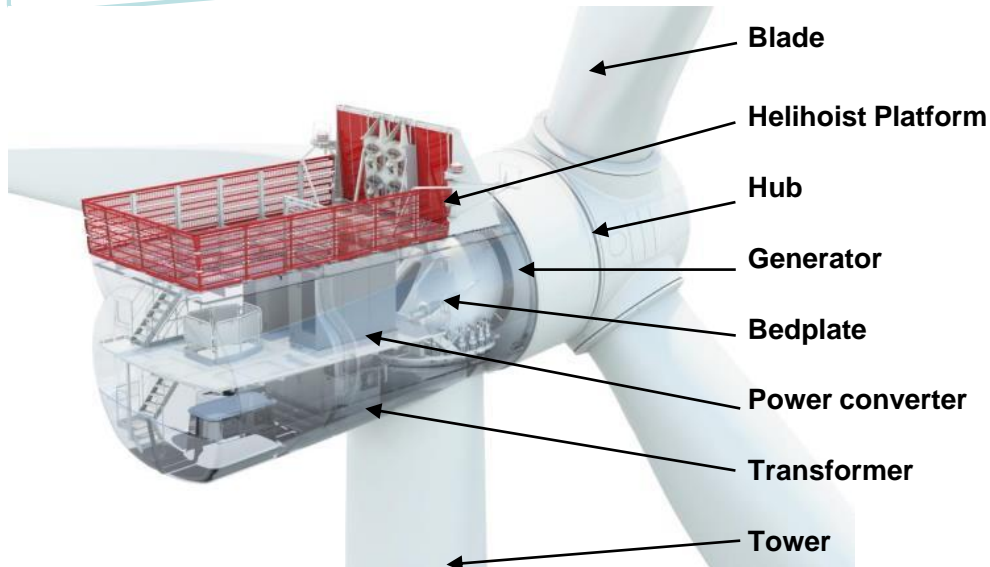
Restricted External  
Communication



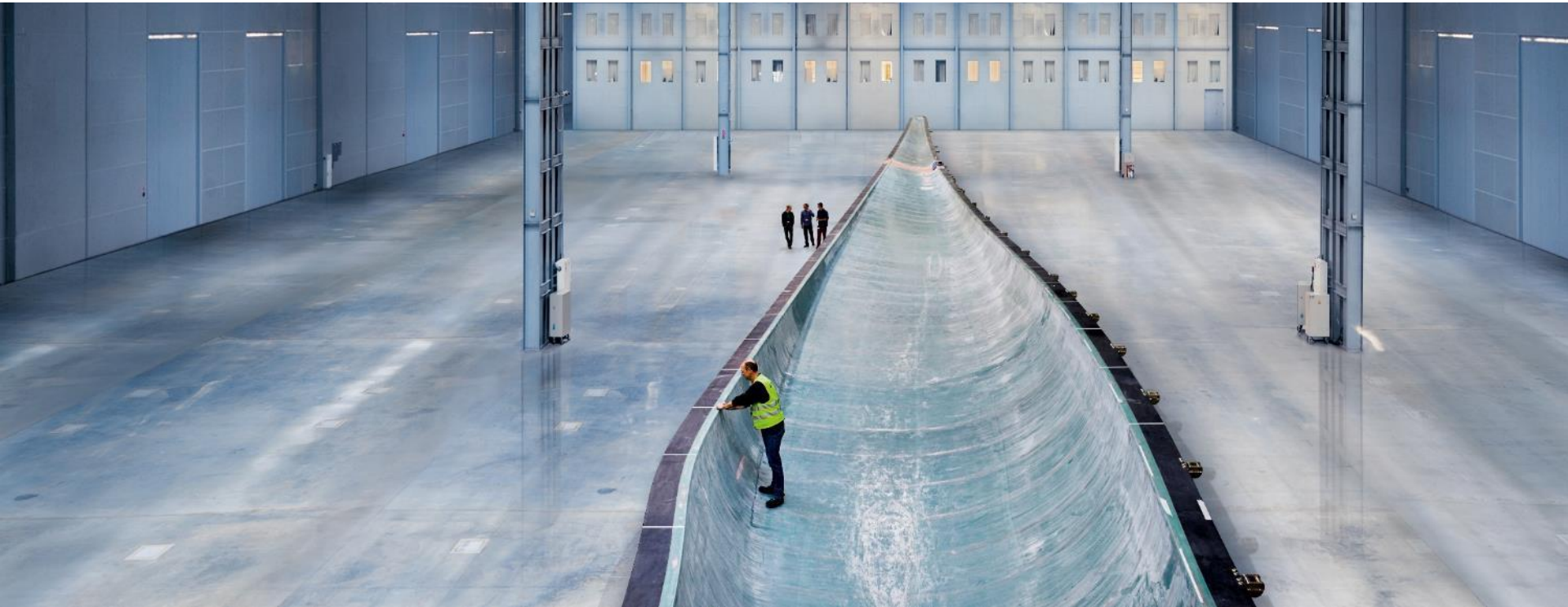


# Siemens 6MW - 154

- 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<sup>2</sup>;
- 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



# Outline of Lecture

Introduction to the Dong Energy

Why Offshore Wind Energy

**Historical Perspective: how we got to here**

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

Future Challenges: 3 key issues

# First Offshore Wind Farm: Vindeby, Denmark



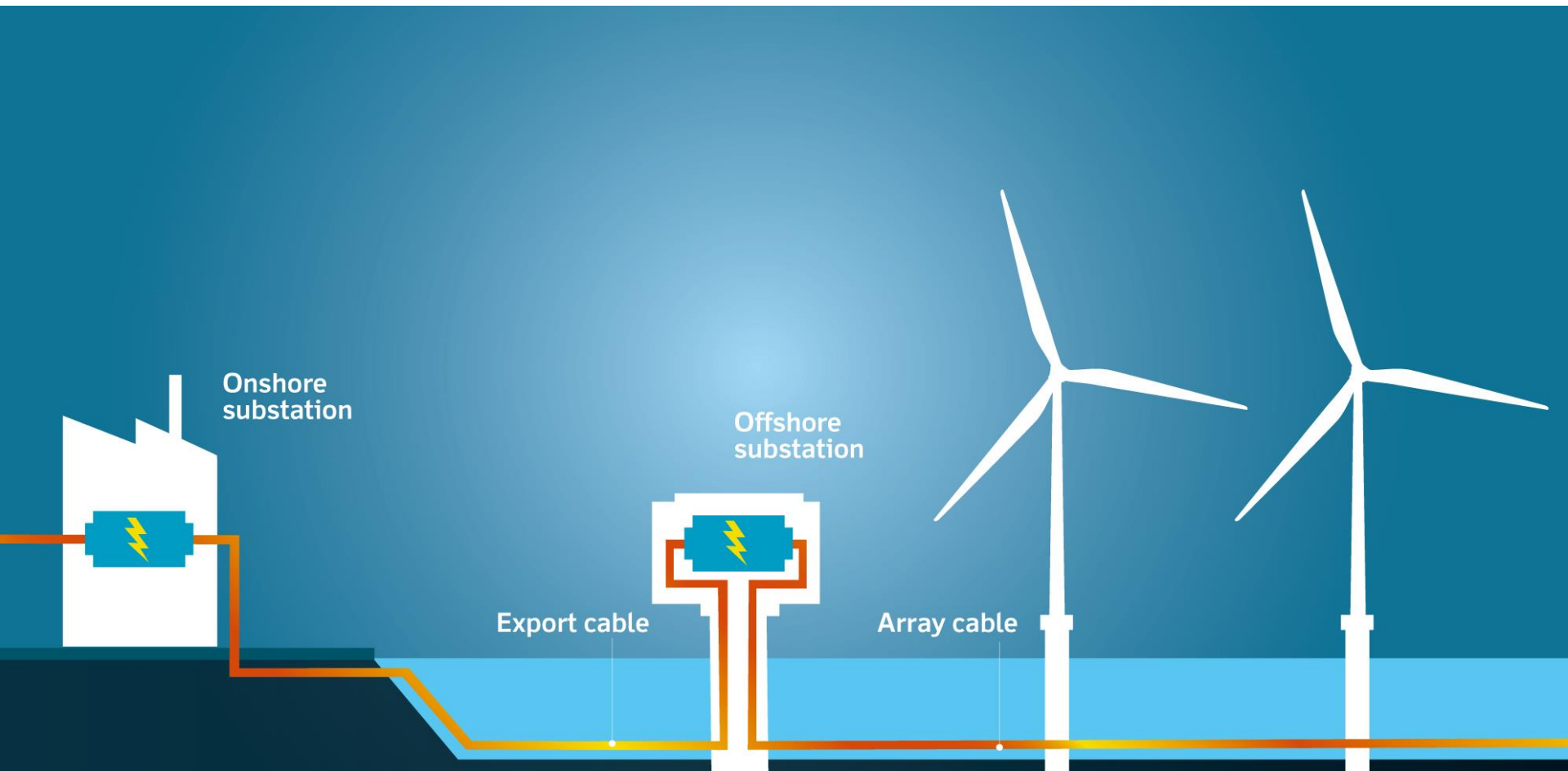
- 1991
- 5MW
- 11 × Bonus (Siemens) wind turbines
- 450kW, 35m Ø Rotor
- 3km from the shore in 2m water
- GBS foundations
- now with DONG Energy
- ~~▪ Still in operation after 25 years!~~
- Currently being decommissioned

# 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

Introduction to the Presenters

Why Offshore Wind Energy?

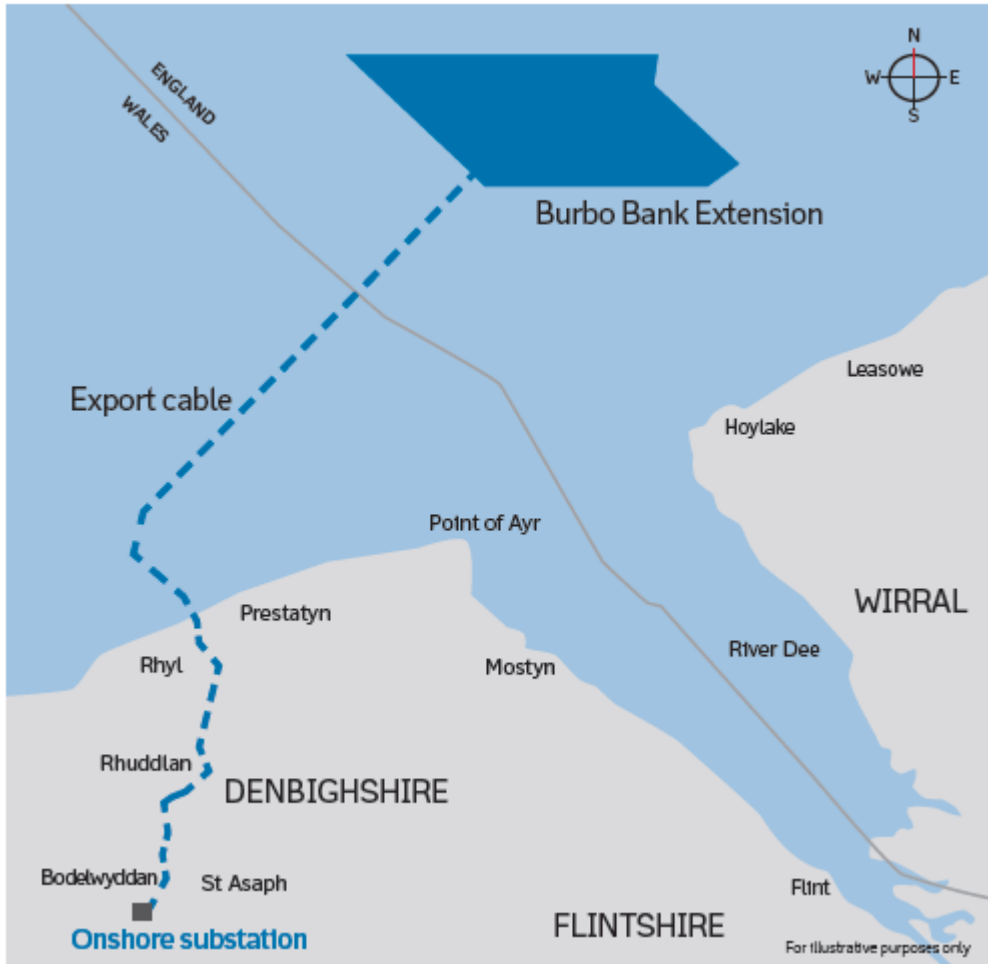
Historical Perspective: how we arrived at today

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

Future Challenges: 3 key issues



# 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 km<sup>2</sup>)

Turbines: 32 x MVOW 8.0-164(258 MW)

Electrical: 33/220/400 kV step-up

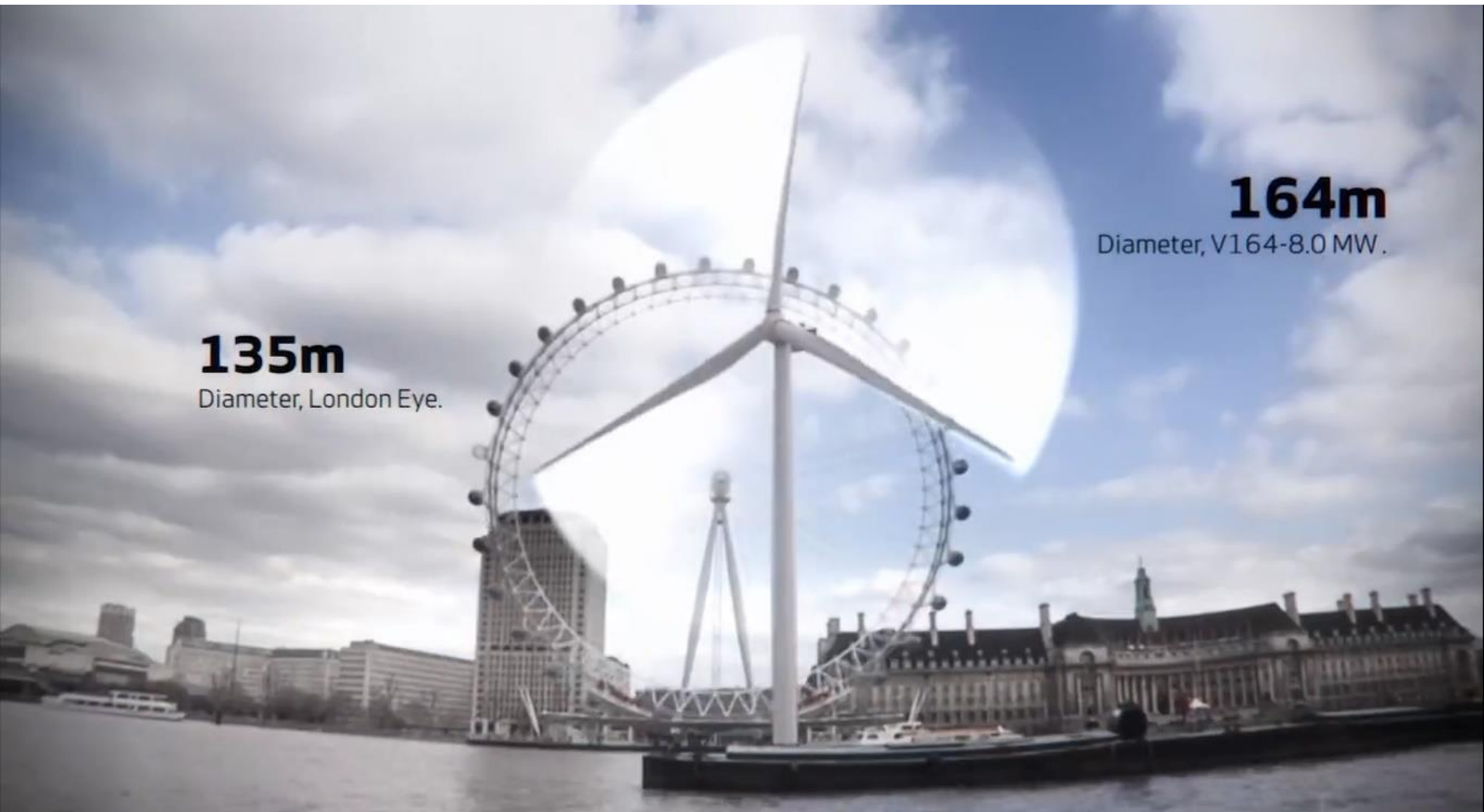
Water Depths: 4 – 17 m LAT

Average wind speed: 9.0 m/s

# Burbo Bank Extension (under construction)



# Burbo Bank Extension is a ground breaking project....



**135m**

Diameter, London Eye.

**164m**

Diameter, V164-8.0 MW.

Photo: Courtesy of MHI Vestas Offshore Wind

# Burbo Bank Extension (complete!)



# Outline of Lecture

Introduction to the Presenters

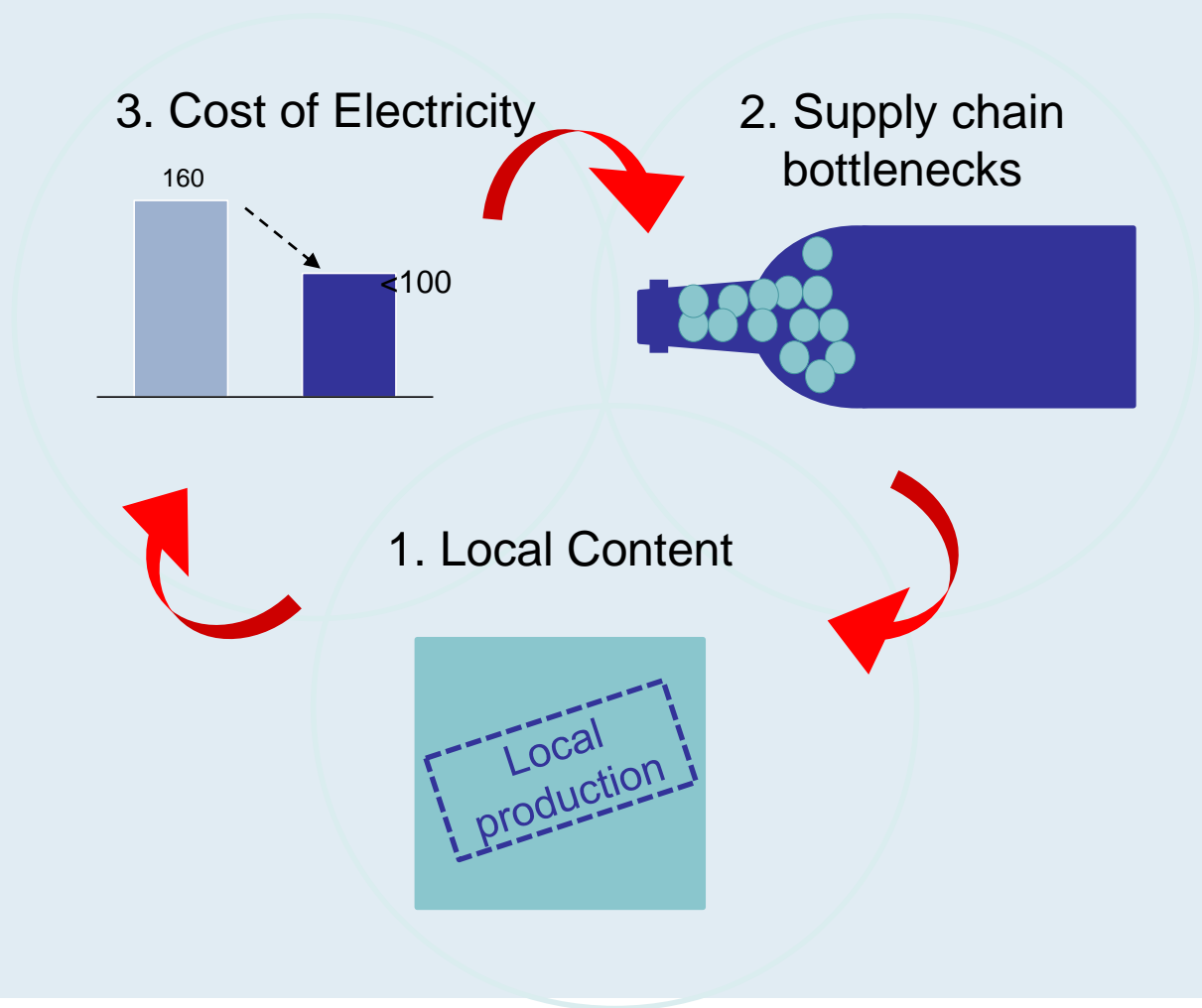
Why Offshore Wind Energy?

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# Key challenges for offshore wind



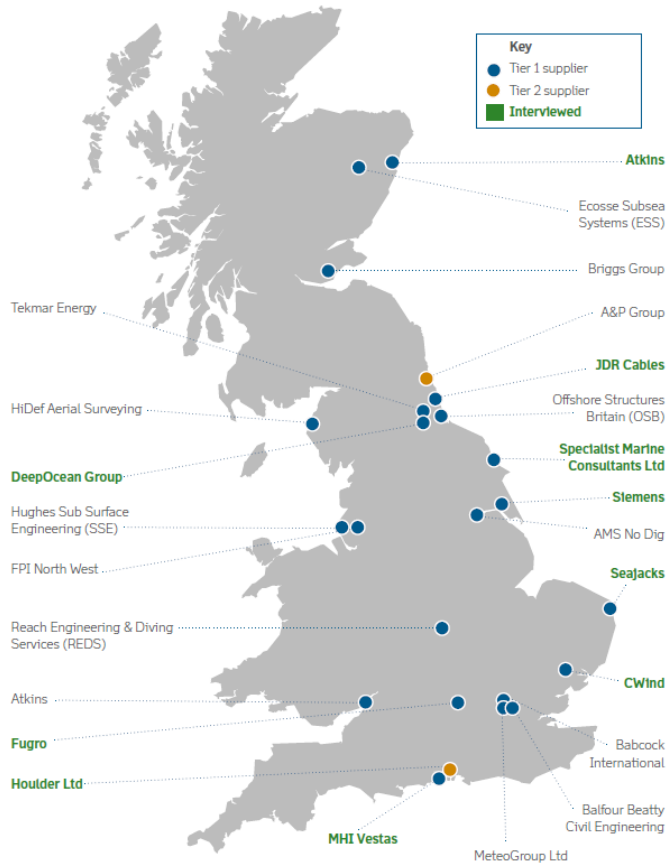
# Challenge 1: Improving UK local content

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

### Our suppliers are based around the country

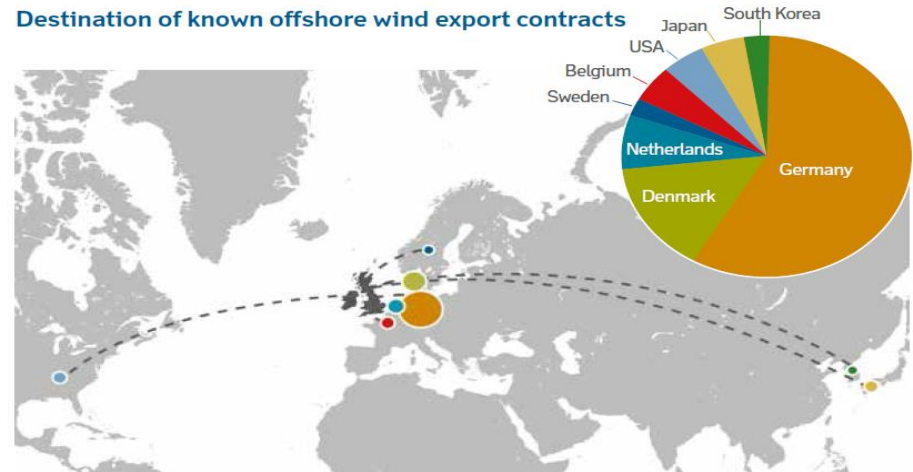
The map below shows the location of the headquarters or main UK facility of some of our tier 1 (direct suppliers) and tier 2 (suppliers to our direct suppliers).

We interviewed the companies in green to get their views on export markets.



- **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.

### Destination of known offshore wind export contracts







# Belfast Harbour

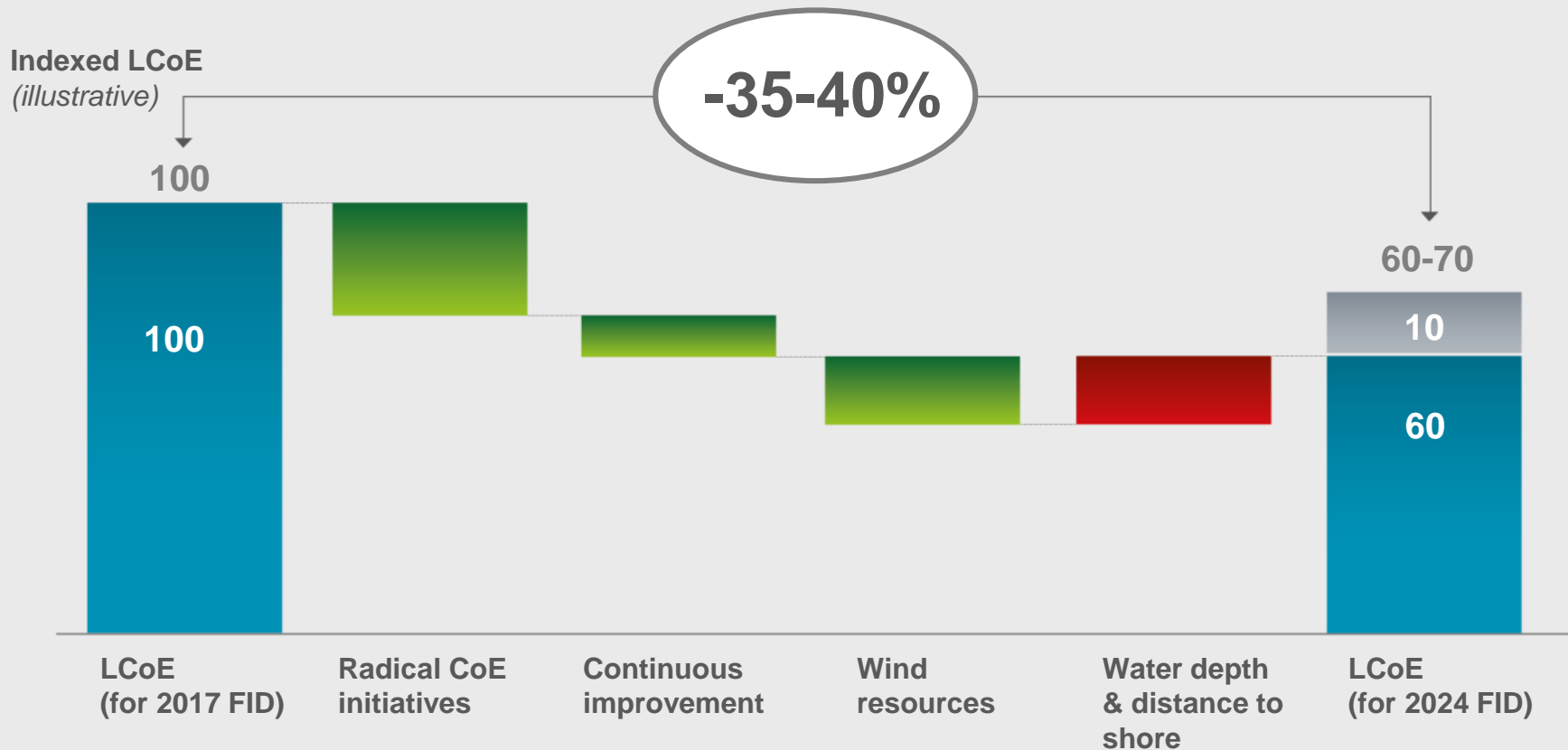




# Challenge 2: Top four current supply chain bottlenecks in Europe

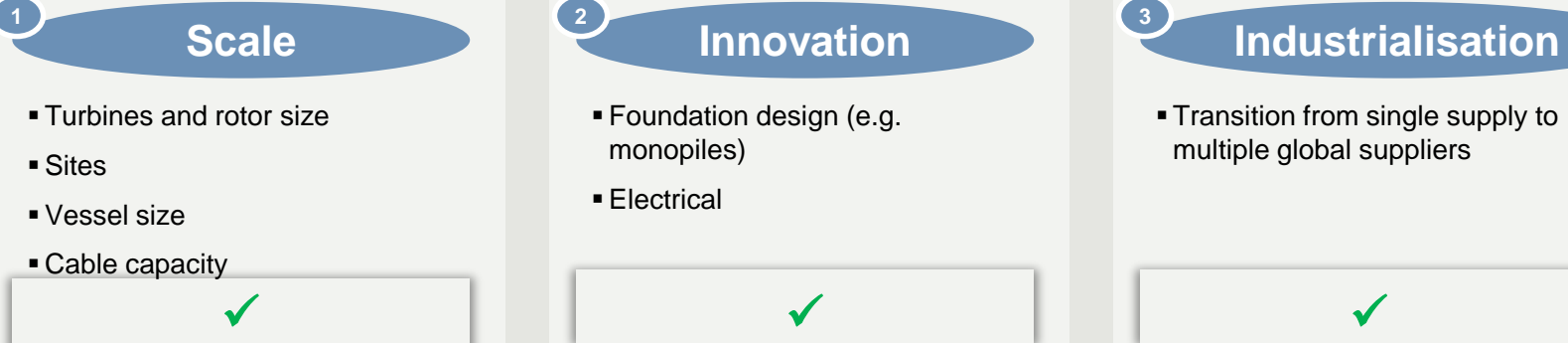
Category	Description	Supply chain risk
<p><b>Subsea export cables</b></p>	<ul style="list-style-type: none"> <li>▪ Few players – all abroad</li> <li>▪ Timescales to increase capacity are tight</li> <li>▪ A few new entrants foreseen</li> </ul>	
<p><b>DC substation electrical systems</b></p>	<ul style="list-style-type: none"> <li>▪ New technology</li> <li>▪ Few suppliers</li> <li>▪ Limited potential for new entrants</li> </ul>	
<p><b>Offshore wind turbines</b></p>	<ul style="list-style-type: none"> <li>▪ Sufficient capacity of 6MW+ WTGs, but little competition and many recent mergers.</li> <li>▪ Few 6MW+ WTGs in development</li> <li>▪ Investment required in manufacturing facilities for larger WTGs.</li> </ul>	
<p><b>Foundation installation</b></p>	<ul style="list-style-type: none"> <li>▪ Sufficient number of vessels, but many are not efficient for installing jacket foundations</li> <li>▪ Few next generation concepts in development, - little consensus on optimal solution</li> </ul>	

## Challenge 3: The cost of energy target will be achieved through improvements within several areas



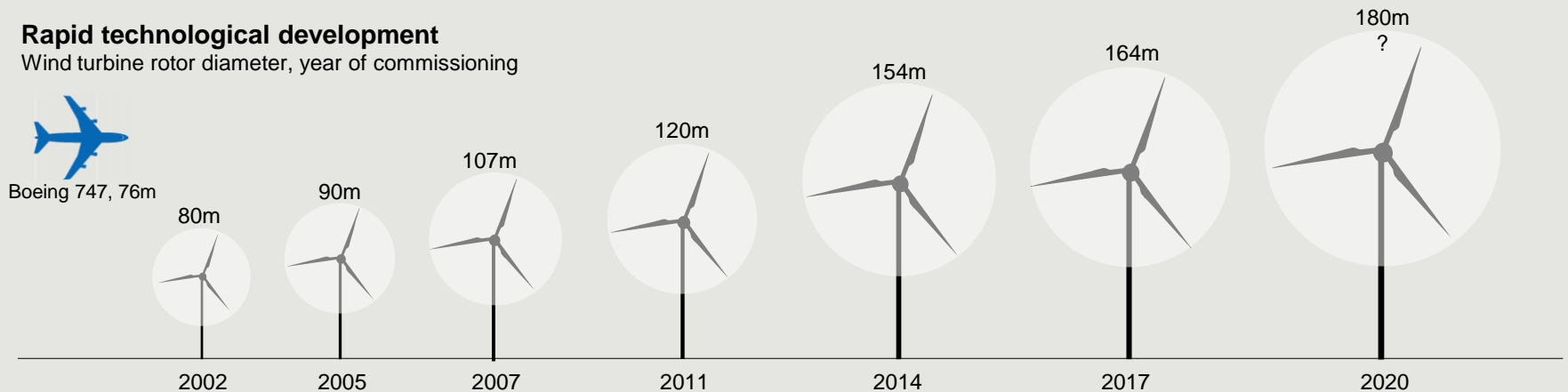
# At the forefront of making the industry cost competitive

## Multiple levers to drive down cost in offshore wind



## Rapid technological development

Wind turbine rotor diameter, year of commissioning

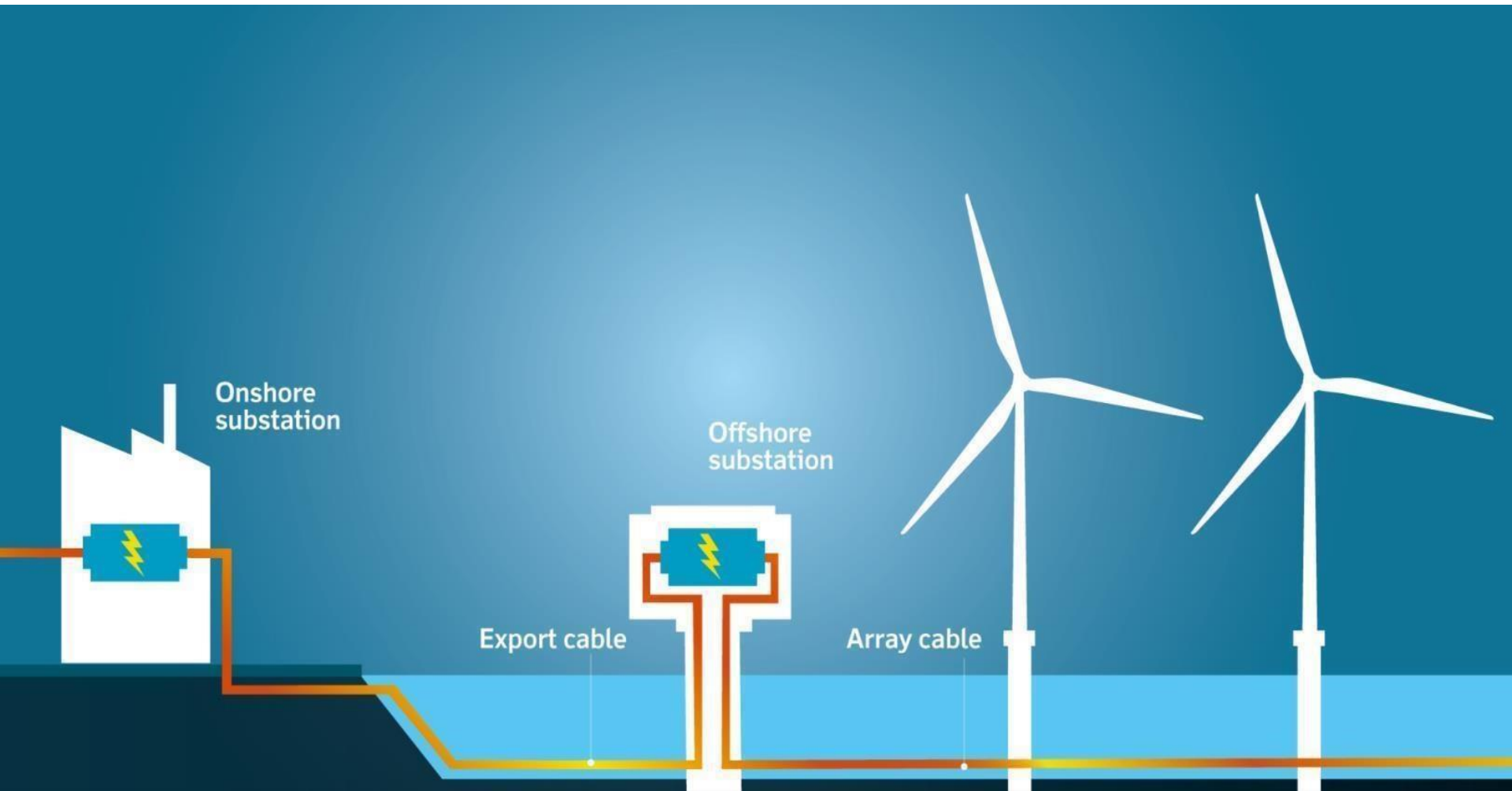


1. Final investment decision (FID). All LCoE estimates assume a WACC of 10%.
2. For UK project with FID taken in 2020, corresponding to CoD in 2023

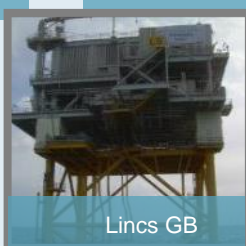
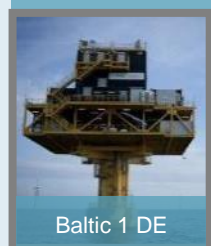
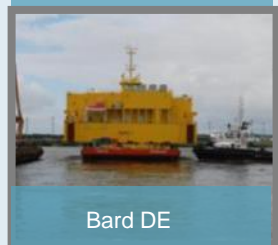
# Wind Turbines – Siemens 3.6-120 with blade improvements



# Standardisation: Simplified offshore wind farm set-up



# Standardisation: Offshore substations 2003 - 2012



# Standardisation: offshore substations

## Standardised modules

Example:  
Offshore substation standardised at c.330 MW



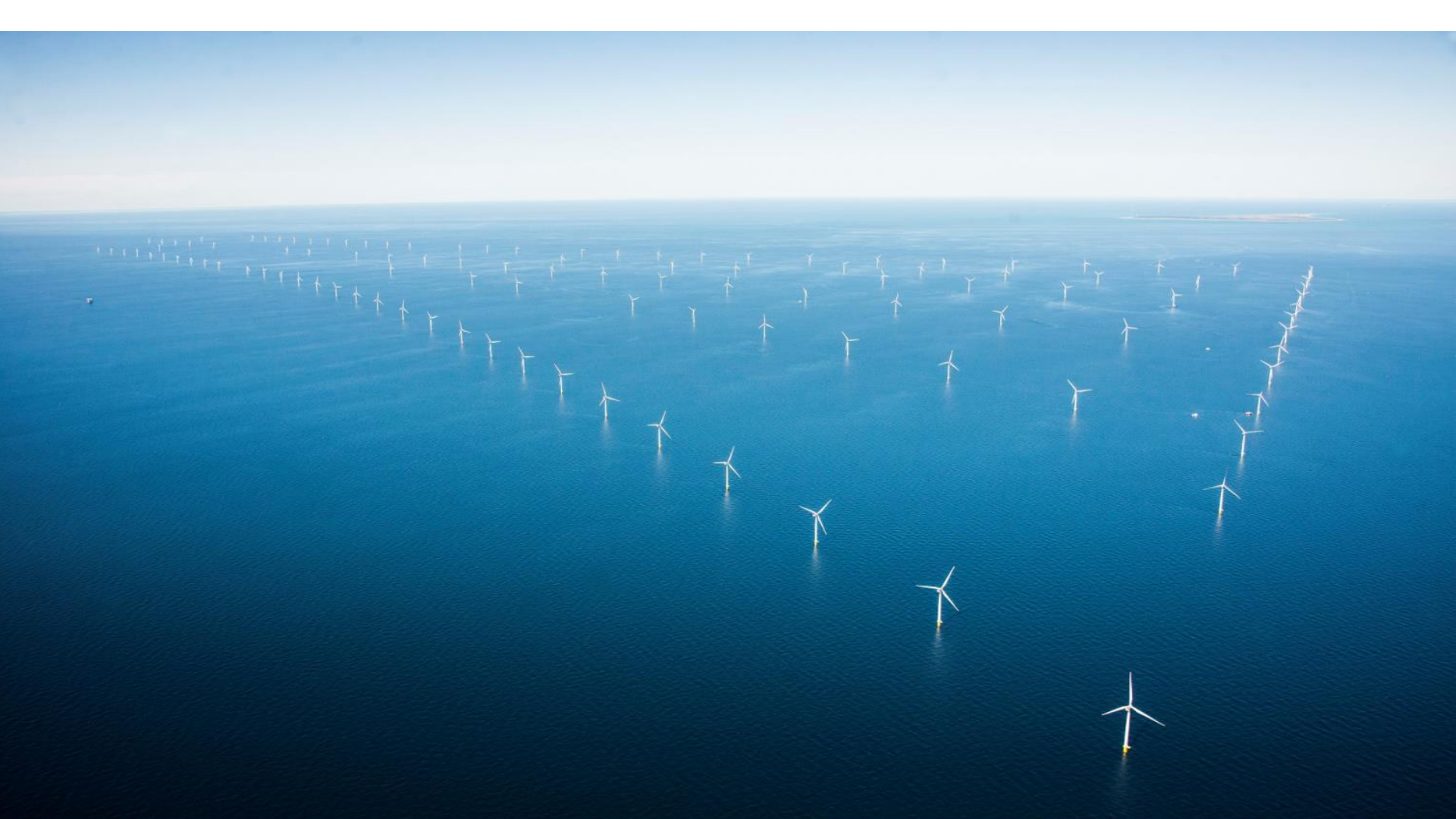
## Applied over several projects

<u>Project</u>	<u>Installation</u>	<u># topsides</u>
Burbo B Ext.	2016	
Race Bank	2017	
Walney Ext.	2018	

## Main benefits

1. Majority of design work performed only once
2. Systematic design for cost approach
3. Convoy procurement (scale, competition)





Anholt



# Mini quiz: ideas/factors to reduce the cost of offshore wind further?

- Revolutionary
- Evolutionary
- Regulatory
- ?

## Where to find out more:

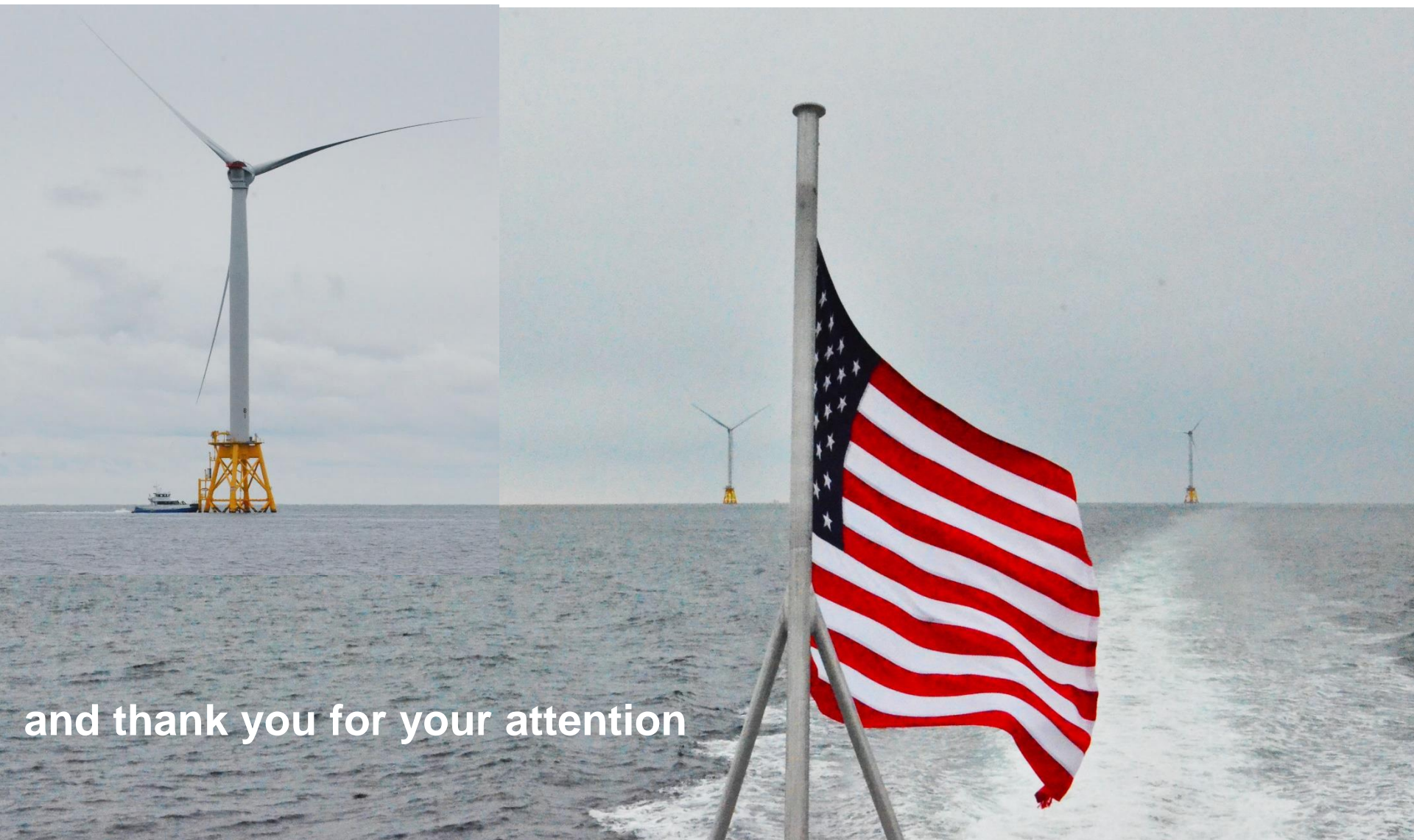
- Windflow: <https://earth.nullschool.net/#current/wind/surface/level/>
- 4C Offshore
  - database of windfarms, windturbines, vessels, ports etc. etc.: <http://www.4coffshore.com/windfarms/>
  - global interactive GIS map: <http://www.4coffshore.com/offshorewind/>
- IEA / GWEC / EWEA and RenewablesUK 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/>
- European Wind contribution: <https://windeurope.org/about-wind/daily-wind/#>
- Carbon Trust – Offshore Wind Accelerator: <http://www.carbontrust.com/our-clients/o/offshore-wind-accelerator>
- DUKES <https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes>
- Gridwatch: <http://www.gridwatch.templar.co.uk/>
- Design Standards and Guidelines (detailed technical information)
  - DNV - Germanischer Lloyd : <https://rules.dnvgl.com/ServiceDocuments/dnvgl/#!/home>
- Offshore wind works: <http://offshorewind.works/>
- DONG Energy Windpower
  - <http://www.dongenergy.com/>

Source:  
<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](http://www.DONGEnergy.co.uk)

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