Offshore Wind Accelerator
Driving down the cost of offshore wind
Our mission is to accelerate the move to a low carbon economy

We cut carbon now by
- Providing specialist advice and finance to help organisations cut carbon
- Setting standards for carbon reduction

We cut future carbon emissions by
- Opening markets for low carbon technologies
- Leading industry collaborations to commercialise technologies
- Investing in early stage low carbon companies
In 2008 Carbon Trust assessed barriers to offshore wind
Offshore wind power: Big challenge, big opportunity

Focus of assessment

– What is required to deliver offshore wind in the UK?

– What does UK Government and industry need to do?

Note: Report is available on our website: www.carbontrust.co.uk
Increased RD&D critical for cost reduction

Weak commercial returns high levels of public subsidy

Current expectation

£75bn

Optimal site availability

£16bn

Cost reductions

£14bn

Achievable goal

£45bn

Requires major RD&D programme, of which OWA is one component

Stronger commercial returns lower levels of public subsidy

Offshore Wind Accelerator is a collaborative RD&D project
Objective: Reduce cost of energy by 10% through RD&D

- 8 developers + Carbon Trust
- 4-year commitment to 2014
  - Started October 2008
- Focusing on technologies for
  - Round 2 extensions
  - Round 3
  - Scottish Territorial Waters
- Total budget ~£40m
  - £10m for collaborative R&D
  - Up to £30m for demonstrations
  - Carbon Trust funds 1/3

60% (30GW) of licensed capacity in UK waters
OWA is an example of market-pull innovation

**Two approaches to innovation**

**Innovators**
- Technology push
- Research-focused
- May not meet customer needs

**Market**
- Market pull
- Customer-focused
- Innovators focus on main challenges

**UK offshore wind R&D**
- Customer-driven

Source: Carbon Trust 2011
OWA engages across industry
Third-parties supplies innovation, supply chain validates it
Focus is on areas developers most able to influence
OWA focuses on strengthening economics of offshore wind

Offshore wind returns

CAPEX

OPEX

Yield

Financing costs

Foundations

Access

Electrical systems

Wake effects

Four technology areas, selected on basis of detailed analysis of over 70 technical barriers
Electrical Systems vision: improve efficiency of collection & transmission

Objectives
Increase efficiency and reliability of collecting and transmitting electricity

To increase the cost effectiveness of deploying such systems
HV Array shows clear advantages

The advantages of higher voltage arrays are:

- The ability to use electrically larger substation transformers.
- The substation transformers are significantly lighter compared to 33kV transformers of the same rating.
- Lower losses in array cables.
- Possible to reduce the number of substation transformers.
- The ability to connect turbine in ‘loops’ to improve availability (Ring network).
Study aim to reduce the cost of energy through the development of higher voltage inter-array systems

- **Design bases**
  - 33kV baseline design

- **Equipment Specification**
  - Equipment development and specification for cables and switchgear

- **Engineering Design**
  - Creating different design scenarios

- **Cost Benefit**
  - Cost benefit analysis
Baseline design used two different network configurations:

- 1GW wind farm
- 5MW turbines
- 200 Turbines
- 3 substations
- 3 transformers per substation
- 22 turbine per transformer

Ring inter-array networks provide redundancy.
New Cable designs are needed

Objective
- Determine technical and economic feasibility of operating inter-array cables (wet cable design) at >33kV, at a similar cost to 33kV cables

Technical challenge
- Prevent water treeing to extend life of higher voltage wet cable designs

- Water treeing has traditionally been prevented in submarine high voltage cables by using water barriers like lead sheath

- Lead sheath (dry design) cable would prove too expensive for array cabling
Cable manufacturers developed promising cable designs

Comparison of 33kV versus 66kV cable

Cost increase

- Small increase in cost

<table>
<thead>
<tr>
<th>33kV Base case</th>
<th>66kV</th>
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</table>

Increase in transmittable power

- Large increase in transmittable power

<table>
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<tr>
<th>33kV Base case</th>
<th>66kV</th>
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</table>
Higher Voltage equipment can be accommodated into current turbines or on structures

Objective
- Accommodate a range of substructure types (mono-piles, jackets, OWA concepts)
- Maintain low cost
- Consider installation and O&M

Three variations for 52kV / 66kV equipment:
- 1: Transformer and switchgear outside on support structure
- 2: Only transformer on the platform
- 3: All equipment inside the tower
Benefits of higher voltage arrays are very sensitive to cable failure rates

<table>
<thead>
<tr>
<th></th>
<th>Cable Failure Rate [failures/km/year]</th>
<th>Mean Time to Repair</th>
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<tbody>
<tr>
<td>Best</td>
<td>0.0008</td>
<td>1 month</td>
</tr>
<tr>
<td>Mid</td>
<td>0.0094</td>
<td>2 month</td>
</tr>
<tr>
<td>Worst</td>
<td>0.015</td>
<td>3 month</td>
</tr>
</tbody>
</table>

Worst cable failure rate means 3 failures per year on a 1 GW wind farm with 200 wind turbines*

Best cable failure rate means one failure every 6 years on a 1 GW wind farm with 200 wind turbines *

* Assuming distance between wind turbines of 1 km and distance from wind turbine to substation of 1 km
Higher voltage ring arrays networks will increase reliability and reduce life cycle cost

- Cost of Energy for Ring Networks

<table>
<thead>
<tr>
<th>Radial Network</th>
<th>Ring Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>66kV</td>
</tr>
<tr>
<td></td>
<td>33kV</td>
</tr>
</tbody>
</table>

Best availability | Mid availability | Worst availability

Cost reduction achieved by:
- Increased redundancy therefore reduced downtime
- Reduced losses in cables
- Number of substation reduced from 3 to 1
Transformers and Switchgear is commercially available for 66kV

<table>
<thead>
<tr>
<th>Transformers</th>
<th>Switchgear</th>
<th>Cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG Global</td>
<td>Schneider</td>
<td>No commercial high voltage inter array cable with required specification and price</td>
</tr>
<tr>
<td>ABB</td>
<td>ABB</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>Siemens</td>
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- Lack of 66kV intra-array cables is the barrier to moving to higher voltage arrays

- Although suppliers including Prysmian and Nexan have suitable designs, they have yet to be qualified and certified
66kV arrays provide benefits to developers and create a market opportunity for the supply chain.

- Over 6000km of cable will be required to build out Round 3.¹
- Manufacturer who can provide 66kV cable will gain competitive advantage.

- Over 6000 turbine transformers and switchgear are required to build out Round 3.
- Increased power rating of turbines will demand higher voltage levels.
- Clear opportunity for suppliers.

¹: Assuming 32GW licencing capacity, 5 MW turbines, distance between wind turbines of 1 km and distance from wind turbine to substation of 1 km.
OWA is keen to co-invest in 66kV cable development

- Our partners consider higher voltage arrays as an opportunity to reduce life cycle cost.
- New cable designs need to be qualified and certified to commercialise them.
- We are keen to work with the supply chain to bring this new technology to market.
- OWA aims to invest in commercialising new cable designs for higher voltage arrays.
- This provides a market opportunity for the supply chain.