THE CROWN ESTATE



Summary report June 2014

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Executive summary



The UK now has 3.7GW of offshore wind capacity in operation providing clean energy for British homes and businesses, and we expect a further 1.4GW of capacity to be completed over the next 12 months. This would take the total operational capacity of offshore wind to over 5GW by 2015. With the Government now providing policy certainty through the Energy Act 2013 and Electricity Market Reform, the offshore wind sector has a clearer idea of capacity to be delivered in the second half of this decade; and we expect to see over 10GW of offshore wind capacity in total operating in UK waters by 2020.

All offshore transmission infrastructure connecting these projects has, to date, been constructed by the developer of the connecting offshore wind farm, with the assets transferred post construction to an Offshore Transmission Owner (OFTO), in accordance with the prevailing regulatory framework. There are therefore a wide range of parties who are involved in the development, construction and operation of offshore transmission infrastructure, which means the knowledge base is wide. This also means that experience is spread across a large number of organisations. Given the volume of offshore wind capacity already connected and the expected future capacity, there is a valuable opportunity now to better understand the challenges faced on offshore transmission projects and capture this knowledge for the benefit of future projects, as a way of contributing to overall cost and risk reduction.

This summary report presents key findings from a wider study The Crown Estate conducted over winter 2013/14 to understand experience and lessons learned in the development, construction and operation of offshore transmission projects to date. The study also considered ways in which the sector could improve the way it shares knowledge going forward in order to contribute to overall cost reduction for offshore wind. Exploring this was one of the key recommendation on grid from the 2012 Offshore Wind Cost Reduction Task Force Report.

To inform the study, a range of industry stakeholders have made important contributions, either through direct interviews or through the process of reviewing outputs. This engagement has been essential as a way of revealing the range and extent of issues faced by stakeholders such as offshore wind developers, OFTOs, manufacturers and installation contractors, and to inform an assessment of ways in which the same issues could be avoided in the future.

The evidence collected broadly revealed that offshore transmission projects have suffered from, and been adversely impacted by, a range of challenges and issues across project life cycles - from consenting and early stage design through to FEED (Front End Engineering Design), installation and operations & maintenance. Whilst not all projects have experienced the same issues, the evidence suggests that most projects have been adversely impacted in some way, typically manifesting in either unexpected cost escalation or needing to undertake extra risk mitigation actions, or both. Root causes of these issues were varied and project specific. Nevertheless, a trend that emerged was that many of the problems cited appeared to have a root cause in the way in which projects have been delivered, rather than technical challenges per se - although it was clear that technical challenges existed as well. Other evidence suggested decisions taken at the design stage 'locked in' problems for later stages of the project life cycle.

Against this backdrop, the majority of stakeholders who were interviewed considered that there was a clear benefit to their organisation from improving the way in which knowledge is shared across the sector. To this end, the study reviewed ways in which the sector shares knowledge at present, and considered if there may be scope for improvement. The study concluded that there would likely be benefits from a more structured approach to knowledge sharing and proposed the development of a sector wide 'knowledge hub' revolving around a number of core activities and defined outputs, for example:

- Coordinating and collating information on lessons learned across the sector (e.g. through regular industry surveys and summarising relevant conference proceedings) and disseminating this information widely to maximise impact,
- Maintaining a database of relevant industry level initiatives and making information and/or links available widely on progress and conclusions where feasible, and
- Intelligently filter the information and data gathered to prioritise emerging issues which require action or further research, and then work with relevant organisations to instigate action

This conclusion was informed by understanding ways in which stakeholders share information at present, and how this is used. It was also informed by experience from other similar industries and across countries, where there are many examples of structured approaches. The study did not consider detailed mechanics of how such a knowledge hub might operate, who would be the appropriate body to have responsibility for it or how it would be funded. These are matters for further consideration.

Whilst these issues are outstanding, indicative analysis by our consultants suggested that avoiding some of the problems that projects have faced on offshore transmission projects to date could reduce the levelised cost of energy (LCOE) of offshore wind projects by up to 6 per cent. Developing a more structured approach to knowledge sharing gives an opportunity to capture some of this potential saving, both through reducing instances of the same mistakes reoccurring across multiple projects and also to facilitate better collaboration to resolving common issues.

This study has had oversight from the Offshore Wind Programme Board Grid Group. It has also had the benefit from review and input by an expert advisory group comprising three senior members of the Institution of Engineering and Technology (IET). This IET group met three times during the study to guide progress, review interpretation of the evidence and recommendations derived as well as providing overall advice on the report content. A statement from the IET is included in this summary report.

Next steps

Following completion of the study, The Crown Estate has sought views from the Offshore Wind Programme Board (OWPB) on the proposed knowledge hub as outlined in the study. The OWPB has endorsed further work in this area to assess implementation.

The Crown Estate is now working with the Offshore Renewable Energy Catapult to assess practical implementation of such a solution during 2014. This will build on the findings from the study, and involve key stakeholders to ensure the needs and requirements of end users are met in order to facilitate improved knowledge sharing across the sector. This approach will help to ensure the resulting framework is an effective part of the toolkit for helping achieve cost reduction in offshore transmission and ultimately for offshore wind.

IET statement

Nigel Fine

Chief Executive & Secretary The Institution of Engineering and Technology

The IET's Energy Sector Executive Committee was invited by The Crown Estate to provide an advisory group of senior IET members for the specification and development of this report and to provide guidance on the findings and recommendations.

The Advisory Group comprised of Professor John Loughhead CEng FIET (IET Past President & Energy Sector Chairman), Dr Simon Harrison CEng FIET (IET Trustee and Energy Policy Panel Chairman) and Dr Nigel Burton CEng FIET (IET Past President and Energy Sector Executive Committee). The group helped to scope the study and met three times during the report development to guide progress, review interpretation of the evidence and recommendations derived as well as providing overall advice on the report content.

Offshore electricity transmission associated with offshore wind energy generation is a new field, and to date the industry has been learning by doing as projects have been developed and delivered by a range of private sector companies. We believe that The Crown Estate's initiative to identify the lessons learned in projects delivered to date; the ways in which this knowledge can be shared; and how the sharing of future knowledge can be enabled, is an invaluable contribution to developing a more cost-effective industry.

The IET Advisory Group believes this report is a fair and comprehensive review of current "Good Practice in Offshore Transmission" and that the conclusions drawn and recommendations made are derived from an objective and informed analysis of the information gathered.

Nigel Fine Chief Executive & Secretary The Institution of Engineering and Technology



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Introduction

The Offshore Wind Cost Reduction Taskforce (CRTF) report¹ made a number of recommendations to help the offshore wind industry achieve a levelised cost of energy (LCOE) of £100/MWh for projects reaching final investment decisions (FID) in 2020.

The CRTF report included four recommendations related to the offshore transmission sector, one of which was to explore the extent to which the sector could improve the way it shares knowledge, lessons learned and overall good practice. The Crown Estate has led work to address this recommendation over the last 6 months (the study); the results of which are summarised in this report.

To support the study, we commissioned DNV GL to address three main aspects:

- i. identifying what lessons have been learned in the development, construction and operation of offshore transmission infrastructure to date,
- ii. assessing ways of improving knowledge sharing in the sector and recommending an approach for doing so, and
- iii. indicatively quantifying the potential benefits of such an approach in terms of LCOE

DNV GL undertook the work between November 2013 and April 2014. Their final report (the full report) is available on The Crown Estate's website: www.thecrownestate.co.uk /energy-infrastructure/offshore-wind-energy/working-withus/strategic-workstreams/grid-and-technology

Approach

Addressing this initiative required a high degree of engagement with key stakeholders involved in the offshore transmission sector in order to understand

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There are opportunities to reduce the cost of transmission and grid connections, and to contribute to the £100/MWh target in the UK Renewable Energy Roadmap.

OFFSHORE WIND COST REDUCTION TASK FORCE June 2012



projects, as well as interrogating evidence from a range of other sources. In particular, primary research was undertaken through semi-structured interviews with 19 industry stakeholders to understand their experience to date, comprising offshore wind developers, Offshore Transmission Owners (OFTOs), Original Equipment Manufacturers (OEMs) and contractors among others.

These interviews were complemented with a literature review of relevant conference proceedings and other public domain reports as well as internal DNV GL knowledge. When considering ways in which the offshore transmission sector could adopt a more structured approach to sharing knowledge and good practice, the consultants reviewed similar schemes in other industries (in the UK and elsewhere) in addition to drawing on feedback collated through the interviews.

Purpose of this report

This report summarises the main findings from the study, focussing on lessons learned and how the sector could better share knowledge and good practice. It is intended to introduce the key elements from the study, and signpost further detail in the full report.

As with the full report, all findings are aggregated to preserve confidentiality.

Structure of this report

The remainder of this report is set out in the following sections:

- Lessons Learned section summarises the key results from the retrospective review of lessons learned to date, and
- Knowledge Sharing section summarises the findings on current initiatives being taken forward across the sector, and outlines an approach to enable the sector to improve the way in which it shares knowledge.

Acknowledgements

The Crown Estate would like to acknowledge the input and support from those organisations that participated in this study: ABB, Balfour Beatty, The Carbon Trust, Centrica, Diamond Transmission, DONG Energy, Fluor, Frontier Power, The Institution of Engineering and Technology, Mainstream Renewable Power, National Grid, nkt cables, Offshore Renewable Energy Catapult, Offshore Wind Programme Board Grid Group, Ofgem, RenewableUK, RWE, Scottish Power Renewables / Iberdrola, Siemens T&D, Statkraft, Statoil, Transmission Investment, Warwick Energy, Van Oord, and Visser & Smit Marine Contracting.

We would also like to acknowledge the work undertaken by DNV GL in support of this initiative.

1 Offshore Wind Cost Reduction Task Force Report, June 2012

Lessons learned in offshore transmission

Between December 2013 and February 2014, DNV GL interviewed a broad range of industry stakeholders in order to understand what issues they had encountered on offshore transmission projects to date, and the impacts of these.

These interviews revealed that offshore transmission projects have suffered from, and been adversely impacted by, a range of challenges and issues across project life cycles – from consenting and early stage design through to FEED, installation and operations & maintenance. Figure 1 illustrates typical issues which interviewees raised.

FIGURE 1: Typical issues identified as adversely impacting offshore transmission projects



Consenting delays

Source: the full report



Whilst not all projects have experienced the same issues, the evidence DNV GL gathered does suggest that most projects have been impacted in some way, typically manifesting in either unexpected cost escalation or needing to undertake extra risk mitigation actions, or both.

The full report details lessons learned across the full life cycle of offshore transmission projects, which for the purpose of this analysis is as set out in Figure 2.



A key finding from the assessment of lessons learned across each life cycle stage was that many of the problems identified had a root cause in the way projects have been managed and delivered, rather than technical challenges – although technical challenges clearly exist as well. Other evidence suggested decisions taken at the design stage 'locked in' challenges for later stages of the project life cycle.

Two key asset areas for offshore transmission systems were looked into and issues with which were raised as recurrent themes in the interviews – (i) export cables and (ii) offshore substations/converter stations. Each is considered below as well as an overview of root causes.

Export cables

There have been a range of well-documented problems with export cables across the industry over at least the last decade. These include manufacturing defects, poor storage, challenges in burying the cable to specified depths, project delays, cost overruns, mismanagement between supply of the cable and installation contractors, unsuccessful horizontal directional drilling (HDD), damage from jack-up vessels, poor landfall design, and poor termination workmanship at the offshore substation. Figure 3 below provides a panoramic picture of some of the issues noted from the public domain sources since 2001.

Figure 3: Export cable issues experienced on offshore windfarm projects



Problems

- Installation problems
- Installation delay
- Kink discovered, remedial work
- Route issues
- Damage
- Anchor damage
- Cable replacement
- 🔺 Cable damage, repair
- Cable repair
- Cable damage
- Cable damage by jack-up

Source: the full report

Impacts from cabling problems such as those cited in Figure 3 include:

- significant remedial work requiring replacement cables, storage sites, additional vessel costs and increased project management costs,
- · delay to start-up of the wind farm,
- lost wind farm generation revenue due to cable damage,
- transfer value determined by Ofgem being less than the actual costs of developing the transmission infrastructure (paid for by the developer under the Generator Build model),
- delay in transferring assets to the OFTO,
- regular ongoing remedial work, and
- claims and counter claims.

Offshore substations / converter stations

Issues with offshore substations and converter stations are less well-documented publicly than export cables, but despite this a range of key challenges were noted during the study including: transformer failure, nonconformities to design specifications, design flaws, manufacturing defects, corrosion, installation delays, access and egress issues, fire, termination interface issues, and poorly designed boundary points.

Impacts from offshore substation and converter station problems such as these have included:

- · delays to start up of the wind farm,
- · cost overruns,
- additional vessel costs,
- significant offshore snagging,
- work exceeding weather windows,
- significant ongoing remedial work, and
- unexpected downtime.

It is important to note that the issues and impacts noted above are based on the evidence provided across many projects and do not infer that all projects have been impacted by all issues.

Root cause analysis

Many of the issues identified appeared to manifest once the asset was installed or operational. However, the evidence suggests that there were many different causes that led to these issues. The fishbone diagrams below summarise these causes and illustrate their effects.

On the left hand side of each diagram, the various causes are shown. These individual causes are grouped together into larger 'themes', which ultimately lead to effects noted on the right hand side. The full report examines in further detail each of the causes identified in these diagrams.

Whilst this 'cause-effect' assessment is necessarily aggregated at a sector level for anonymity, it illustrates a myriad of issues have led to challenges in the execution of projects. This suggests there should be a high degree of value in sharing knowledge in order to help mitigate future problems.



EFFECTS

Delays Cost overruns Standby vessel cost Exceeding weather window Additional vessel cost Spare cable cost Additional project management Lost revenue Lower transfer value Delays in transferring assets Claims and counter claims Ongoing

remedial work

EFFECTS

Delays Cost overruns Standby vessel cost Exceeding weather window Additional vessel cost Remedial work Additional project management Lost revenue Lower transfer value Corrosion Claims and counter claims

Source: the full report

Learning from the lessons

Based on the evidence gathered during the study, it is possible to draw direct and indirect learning from the lessons to help mitigate some of the issues identified arising in the future. Table 1 summarises these at each life cycle stage. This table is not intended to be exhaustive, and only reflects on the issues identified as part of the study. Undoubtedly, other problems have occurred with the development of offshore transmission infrastructure which is not reflected. Nevertheless, it provides a wide-ranging account of areas in which there may be improvements which, if made, should reduce unnecessary cost and risk.

TABLE 1: Learning from the past lessons in offshore transmission		
Project Management & Delivery	Technical and Other Areas	
Lifecycle Stage: Consenting		
Consider lifecycle impacts of consenting decisions	Use risk based burial indices to define consent condition on burial depth	
	Collect sufficient survey data along entire cable route	
Lifecycle Stage: Design		
Develop a robust risk management framework	Consider system standardisation of capacity ratings and voltage levels	
Involve supply chains in the design phase	Use reference design(s) for offshore substations if possible	
Consider lifecycle costs	Overplant, subject to Cost Benefit Analysis	
	Optimise approach to rating of cables and transformers	
	Optimise reactive power compensation	
	Avoid monopiles in areas with significant wave interaction	
	Design in better condition monitoring systems	
	Focus on designing out corrosion risk	
Lifecycle Stage: Procurement		
Focus on interfaces	Seek to increase competition in supply chains	
Ensure risk is identified appropriately and managed by the entity best able to do so		
Choose best value not cheapest		
Ensure clear OFTO split in contracts		
Consider use of 'reasonable endeavour (with detailed measures specified)' clause in contracts		
Avoid design changes during fabrication		
Ensure close and competent supervision		
Lifecvcle Stage: Installation		
Plan with realistic programme, with appropriate mitigations and contingencies	'Fingerprint' export cable with as-laid documentation	
Ensure development team are on site		
Use experienced contractors		
Lifecycle Stage: Asset Transfer		
Ensure robust process for collecting as-built drawings, records, etc.	Undertake full suite of surveys and tests before handover	
Lifecycle Stage: Operations & Maintenance		
Plan for cable failure prevention, root cause analysis and cable repair	Develop industry wide good practice in cable surveying	
Use a risk based inspection programme		
Explore cable repair framework agreements		

Source: Edited from the full report

Improving knowledge sharing

The second main aspect of the study was to consider the scope for improvement in the way in which the offshore transmission sector shares knowledge, taking into account factors such as the structure of the sector (which is characterised by a large number of organisations involved across multiple and, in many cases, discrete stages). As part of this, it considered the extent of initiatives that are either ongoing or planned to address specific issues and the parties that are taking these forward.

The existing landscape

The study considered the current landscape of existing and planned initiatives to understand extent of activity and how information is disseminated to stakeholders. The purpose of this was not to seek to review the effectiveness or relative merits of any specific initiative; each will have its own driver and business case. This consideration was to attempt to map the range of initiatives ongoing to respective organisations, as a way of better understanding the breadth of issues that are being considered at the current time.

A summary of organisations involved in research, policy development or establishing technical rules, and some of the key initiatives that they are either progressing or are expected to take forward (at the time of publication) are outlined in Table 2.

Whilst the organisations and initiatives outlined in Table 2 are by no means exhaustive, the findings illustrate that there is a significant volume of activity ongoing, and that the initiatives broadly tackle some of the key learning areas identified in the study. Further, each initiative in its own way has the effect bringing together relevant stakeholders to facilitate a degree of knowledge sharing, whether this is a direct objective or a beneficial by-product of the initiative.

TABLE 2: Range of industry initiatives impacting offshore transmission	
Initiative(s)	
Innovation funding such as through the Offshore Wind Competent Technologies Development & Demonstration Scheme	
Implementing changes to law (such as the 'Commissioning Clause' in the Energy Act 2013)	
Coordination project / Anticipatory Investment	
Integrated Transmission Planning and Regulation (ITPR) project	
Publishing OFTO transfer cost assessment reports	
Consultation on proposed cost benchmarking	
Harmonics working group and related follow on actions	
Network Innovation Competition (NIC)	
 Various working groups looking at all aspects of transmission. Relevant ones include: Service experience review of HV underground and submarine cable systems Testing recommendations for submarine power cables Design and construction guidelines for AC offshore substations for wind power plants Special considerations for AC collector systems and substations associated with HVDC connected wind power plants 	
Consolidation of industry practice into minimum standardised approaches	
DNV-RP-J301, "Subsea power cables in shallow water renewable energy applications" (following Joint Industry Project)	
Joint Industry Project on HVDC qualification	
Offshore substation standard – DNV-OS-J201 and GL guideline	
Investigation into the need, implementability and potential benefits of a 'Modular Approach to Offshore Transmission Systems' discussing standardisation at the system level	
Principles of cable routeing and spacing/proximity	
Sharing lessons learned and good practice in offshore transmission	

TABLE 2: Range of industry initiatives impacting offshore transmission continued		
Organisation	Initiative(s)	
The Carbon Trust	Cable Installation working group Cable burial and risk mitigation project Free-hanging cables 	
	Electrical working group Optimising AC system design Optimising HVDC system design 	
Insurers European Wind Turbine Committee	Draft Offshore Code of Practice for Offshore Wind Projects. At present this is focused on array cables but has some applicability to export cables	
Offshore Wind Programme Board	Grid Group Standardisation Sharing good practice 	
	 Contracting Strategy Group Exploring pre and post FID engagement strategies Defining alliancing approaches Shortlist of contracting approaches to help support appropriate risk transfer and collaboration 	
Conferences	Numerous industry conferences exist often focused on project experience e.g. EWEA, RenewableUK, Windpower Monthly, International Cabling, International Substation Design and Subsea Power Cables. There are a range of more technical conferences as well e.g. Annual Wind Integration Workshop, CIGRE sessions etc	
Other working groups and industry forums	RenewableUK Grid and Offshore Grid Groups	
	Electricity Networks Association OFTO Forum	
	Subsea Cables UK Renewables sub-group	
	Society of Underwater Technology OSIC group	
	Electricity Networks Strategy Group	

Source: Edited from the full report

However, the study also found there is little structure as to organising initiatives or, more importantly, in terms of disseminating wider learning from the outcomes. Linked to this, feedback from participants suggested that there is a disparity across different stakeholders of the extent of knowledge about the range of initiatives ongoing at any one time. If this is the case, it would appear to be a clear limiting factor to the sector generally in terms of absorbing the benefits from the learning and knowledge generated through these initiatives.

A more structured approach

The study noted that whilst there is evidence of learning and knowledge being shared across the sector to date (as summarised in Table 2), more effective knowledge management and transfer could be achieved if it were more coordinated. This was supported by interviewees, who believed that improved knowledge sharing would benefit their organisation².

To better understand potential effects of improved knowledge sharing, the study sought to understand how other similar sectors have addressed this issue, and found that a coordinated approach to knowledge sharing is not uncommon. For example, both the Norwegian FPSO (Floating Production, Storage and Offloading) Experience Transfer Network³ and SKYbrary⁴ were highlighted as positive examples of where an industry has worked together effectively to share information in order to manage cost and/or mitigate risks. Further detail on these is set out in the full report.

Against this backdrop, the study concluded that there would likely be benefits from a more structured approach to knowledge sharing and proposed the development of a sector wide 'knowledge hub' revolving around a number of core activities and defined outputs, for example:

- Coordinating and collating information on lessons learned across the sector (e.g. through regular industry surveys and summarising relevant conference proceedings) and disseminating this information widely to maximise impact such as through regular e-bulletins,
- Maintaining a database of relevant industry level initiatives and making information and/or links available widely on progress and conclusions where feasible, and
- Intelligently filter the information and data gathered to prioritise emerging issues which require action or further

² See Fig 5-3 in the full report

³ A Norwegian oil and gas initiative aimed at enabling learning to improve future designs.

⁴ An aviation sector initiative aimed at collating safety knowledge related to air traffic management and aviation safety.

research, and then work with relevant organisations to instigate actions.

On the latter point above, the study has already identified a number of initiatives that could be taken forward based on feedback collected as part of this study, which are summarised in the Appendix.

An illustration of how the proposed knowledge hub could work is set out in Figure 6.

Why do this?

The report outlines a proposed approach to improving the way the sector shares knowledge and learning going forward. Further work will be required to fully assess whether this is the right model for the offshore transmission sector and also quantify costs and benefits. Nevertheless, a high level consideration of issues has been covered to better understand the rationale for pursuing this further.

A challenge with assessing the benefits of knowledge sharing is the difficulty in observing and measuring direct effects. As a proxy for this, indicative analysis by DNV GL in the study suggests that avoiding some of the problems that projects have faced on offshore transmission infrastructure to date could reduce the LCOE of offshore wind projects by up to 6%⁵. Developing a more structured approach to knowledge sharing gives an opportunity to capture some of this potential saving, both through helping reduce the chances of the same mistakes reoccurring



5 This estimate includes a number of key assumptions around the potential capex and opex impacts of the problems encountered and the additive nature of these on projects. Assumptions and caveats are set out in the full report.

across multiple projects and also through facilitating improved collaboration to resolving common issues.

Considering specific costs was outside of the remit of the study. However it did identify the broad categories of cost which would need to be considered including costs for: detailed design of the scheme, industry engagement to ensure it meets users' needs, set up, and enduring operation.

Community of practice – the users

Effective knowledge management requires that key users of information are identified and fully engaged. Such a 'community of practice' would need to be established if a knowledge hub for the offshore transmission sector is taken forward. Our initial thinking is that this community could comprise Electrical/Grid Package Managers within offshore wind developers and O&M Managers within OFTOs, given that the experience and knowledge of these individuals would be central to realising the potential benefits from enhanced knowledge sharing. However, whilst these may form a nucleus of primary users, interfaces would likely need to be established with other stakeholders, for example within the supply chain and installation contractors.

Next steps

If the knowledge hub outlined above is to be taken forward, key decisions will be required on fundamentals such as the appropriate ownership model, operation, and how it is funded. To inform these decisions, The Crown Estate is working with the Offshore Renewable Energy Catapult to assess practical implementation, including to:

- identify in detail stakeholder requirements for a knowledge hub,
- develop a project definition document for a solution, based on the outline in the full report. This is expected to include defining core outputs, information flows, and governance arrangements, and
- consider funding mechanisms during both the set up and enduring operations phase.

This work will progress during 2014 and will involve key stakeholders to ensure the needs and requirements of end users are met in order to facilitate improved knowledge sharing across the sector. This approach will help to ensure the resulting framework is an effective part of the toolkit for helping achieve cost reduction in offshore transmission and ultimately for offshore wind.







Appendix: Initiatives for further consideration

Based on the feedback from the interviews and other research supporting the study, the following initiatives have been identified as warranting further consideration under the framework of the knowledge hub. Each will require a detailed business case to define scope and need in due course, but this list provides a starting point for further consideration.

TABLE A1: Potential future initiatives

System standardisation

To date, transmission for offshore wind farms has been built with a variety of voltage and capacity ratings which limits compatibility and drives up costs. Technical standards bodies (like IEC, BSI, etc.) or technical guidance bodies (like CIGRE, etc.) only spell out what should be done in terms of material and component design for a given voltage level. They do not specify what the voltage should be in offshore transmission. In other words, system voltage level is an input rather than output in many technical standards. Yet failure to agree a set of common voltage levels will likely increase cost over the lifetime of the asset, because limited compatibility between wind farms will increase spares cost provision and may limit standard asset management approaches.

Further work is necessary to progress, promote and facilitate improved standardisation. A possibly effective way to promote and implement standardisation may be via regulators' guidance on cost assessment of offshore transmission infrastructure (in the case of GB) or via central planning bodies' plans (for example TSOs or ENTSO-E).

Visibility of operational cost and failure data

Good quality data is necessary to develop robust benchmarks to drive better designs for equipment and operating models. However, consistent data sets on key offshore transmission parameters are currently not that visible.

Cost benchmarking is favoured by Ofgem for network regulation and they are consulting on ways to achieve this in the sector. CIGRE provides failure data on a 5-10 year basis but little is available on offshore transmission to date.

There is likely to be benefit in developing systems which enable better quality data to be reported and collated. This is starting to happen in the offshore wind sector, and there may be a case to cover offshore transmission as well.

Overplanting

Evidence suggests developers are seeking to identify the right balance between optimising transmission capacity against installed generation capacity in what is known as 'overplanting'. Internal modelling work by DNV GL suggest that the generating capacity can be increased by around 8% (through a greater number of wind turbines) for the same transmission asset (although this depends on project specific factors), with the corresponding benefit in Annual Energy Production outweighing the increase in Capex and Opex. The Carbon Trust AC Optimisation study may consider this issue but if not there may be benefit in exploring it at industry level, perhaps through a Joint Industry Project.

Base and dynamic asset rating

Estimates for the current-carrying capacity of cables tend to be conservative and export cables in subsea applications are rarely fully utilised (unless 'Overplanting' has been applied).

Cable design is often carried out in accordance with IEC 60287 series of standards to determine the limit of the continuous rated current (100% load factor) at maximum allowed conductor temperature (e.g. +90°C) for the assumed surrounding conditions. Cyclic HV cable rating is covered in IEC 60853-2 but only applies "to cables buried in the ground, either directly or in ducts, when carrying a load which varies cyclically over a 24 h period, the shape of each daily cycle being substantially the same". A generally agreed approach for renewable energy applications which takes due consideration of site specific wind patterns and predicted loading of the cable is yet to be developed.

There appears to be benefit in developing a UK-led 'white paper' for base and dynamic cable rating in offshore renewable applications for soonest application. With more experience becoming available, this could be turned into standard practice in the longer term, e.g. by publication through CIGRE or IEC.

Separately, a detailed base and dynamic rating approach may also be developed for transformers.

Continued overleaf

Optimisation of reactive power requirements

A number of interviewees in the study suggested that reactive power requirements were overly conservative, with too little optimisation across the system. Interviewees suggested the underlying assumptions upon which the Grid Code requirements were based may no longer be as valid and may be worth revisiting.

The Carbon Trust are exploring different technical approaches to optimising reactive power requirements. Beyond this initial work, any change would require agreement from key bodies such as Ofgem and National Grid and there may be a case for starting this engagement early.

16²/₃ Hz transmission

As a potential alternative option to the standard 50Hz AC and HVDC transmission, the industry is beginning to explore the feasibility of low frequency AC transmission (LFAC, such as 16 $^{2}/_{3}$ Hz), particularly in Germany.

Standardising cable surveying and repair approaches

A number of OFTOs in the study highlighted the lack of an industry approach to cable surveying, monitoring and repair once commissioned. A key message was that the data collected was often not comparable, limiting its usefulness. There appears to be scope for a new initiative to resolve this issue.

Lessons learned asset transfer workshop

Ofgem produce a cost assessment report for every asset transferred to an OFTO. This details the evolution of the transfer price and the rationale for changes. It also provides a lot of learning and experience and is considered by interviewees as a useful resource. However, there would appear to be benefit of holding a lessons learned workshop between Ofgem, OFTOs and the developer after asset transfer to discuss any learning from the process. This should be in public to help future OFTOs and developers improve their own asset transfer process.

Edited from the full report



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Correct as of June 2014

The Crown Estate is an independent commercial business created by Act of Parliament. We invest in and manage some of the UK's most iconic assets, including the seabed: managing it effectively and sustainably, balancing different interests and delivering best value over the long-term.

This gives us a unique role to play in developing and helping sustain the UK's energy supply and infrastructure, by working in partnership with a wide range of organisations that have interests in the seabed.

These include wind, wave and tidal power, carbon capture and storage, gas storage, marine aggregates and minerals, cables and pipelines.

We are active asset managers, applying our experience, skills and understanding to deliver optimum returns, create opportunities for ourselves and our partners, and provide a quality service to our customers.

Aware of our monopoly position and the impact of our activities, we are careful to comply with competition laws, co-exist with the wider marine community, and be open and transparent in our dealings.

Because of who we are, we are able to see the bigger picture, making best use of the seabed, and supporting and investing in sustainable development for the long-term benefit of the whole of the UK, now and in the future. Over the past ten years The Crown Estate has paid over £2 billion to the Treasury.