DNV·GL

COST REDUCTION MONITORING FRAMEWORK

Summary Report

Offshore Renewable Energy Catapult

Report No.: 8, Rev. G
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Task and objective:

To provide a bottom up, qualitative assessment of the offshore wind industry's progress against the £100/MWh at FID 2020 target and in turn identify barriers to and recommendations for achieving this.

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	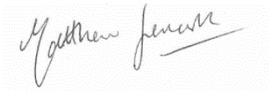	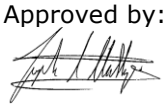
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Keywords:

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Reference to part of this report which may lead to misinterpretation is not permissible.

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A	25/11/2014	First Draft	Paul Reynolds	Matt Levenston	Joe Phillips
B	16/12/2014	Revised following Client comments	Paul Reynolds	Joe Phillips	Joe Phillips
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G	12/03/2015	Correction of minor formatting error	Paul Reynolds	Joe Phillips	Joe Phillips

Table of contents

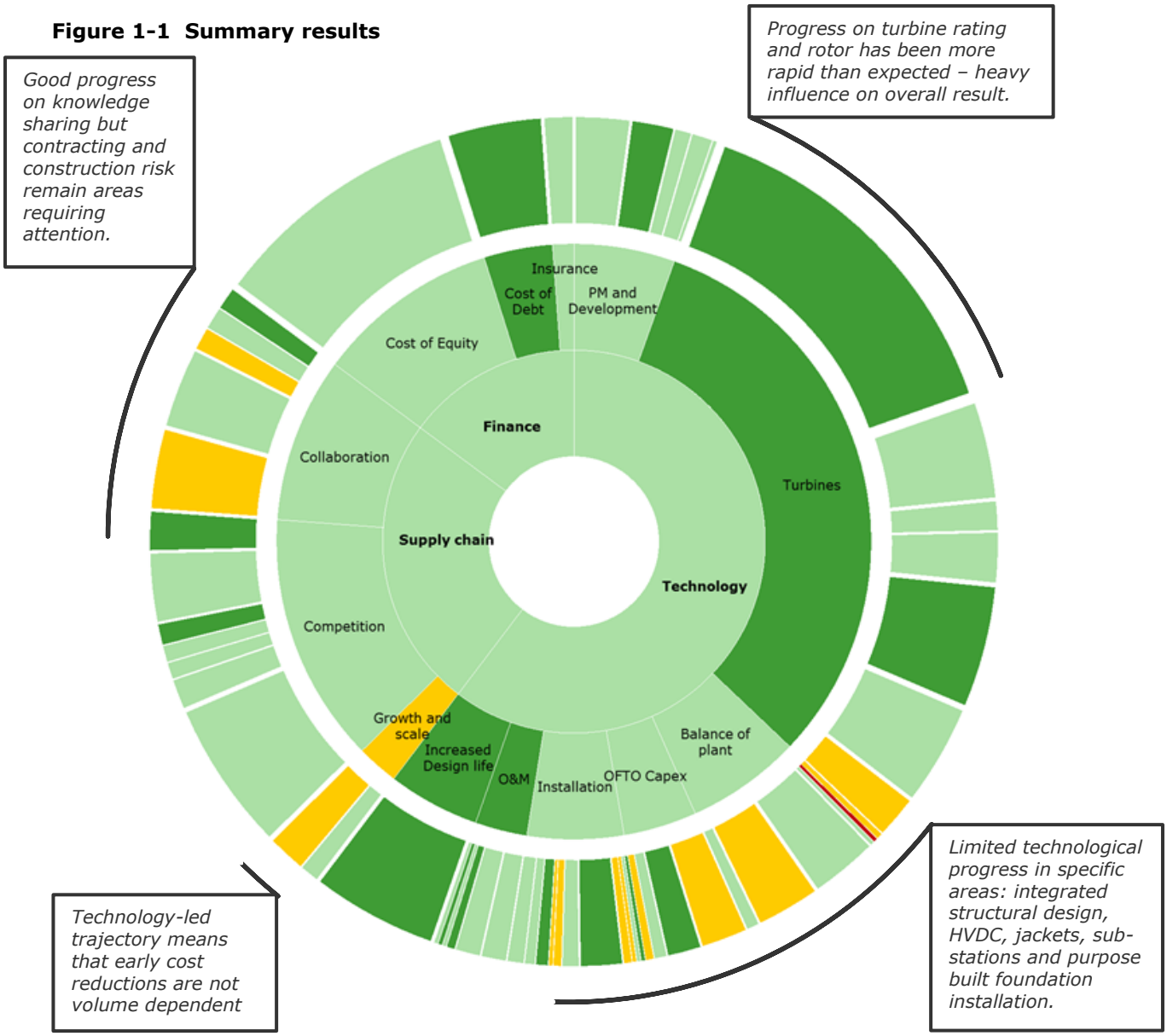
1 EXECUTIVE SUMMARY

The ORE Catapult, in conjunction with The Crown Estate, is developing a Cost Reduction Monitoring Framework (CRMF), on behalf of the Offshore Wind Programme Board and the members of the Offshore Wind Industry Council. The CRMF is seeking to track the industry's progress to £100/MWh at Final Investment Decision (FID) in 2020. This report is the summary of the results of the qualitative element for 2014.

The study draws on and updates the analysis within the Cost Reduction Pathways Study, which predicted relatively little LCOE reduction by 2014 in all three stories.

In this context, DNV GL and PWC conclude that in 2014 the offshore wind industry is **'on target'** to meeting the £100/MWh at FID 2020 target. This is driven by rapid technological progress, in particular in turbines, XL monopiles, O&M and design life. Good progress has been achieved in other areas with both the finance and supply chain workstreams assessed as 'on target'. Growth and scale is the only indicator assessed as being 'behind target'. Figure 1-1 provides the summary of the workstream and the Level 1, 2 and 3 indicators.

Figure 1-1 Summary results



Looking forward, the sector faces a number of challenges and risks to continued progress. Most notably:

Volume

The cost reduction pathways predicted in the various stories within the Pathways Study were largely independent of volume out to 2014, but then diverged out to 2017 and beyond. The analysis within the CRMF concurs with this, with the sector on track even with growth and scale tracking behind target. This appears to be due to the potential short-term benefits of reduced volume on competition, site selection and reduced risk of capital shortfalls.

Going forward, however, the sector will need to achieve rapid cost reductions on the basis of reduced deployment volumes. This may be possible, particularly if wind turbine technology continues to develop rapidly and lower volumes reduce the risk of finance and supply shortages. However, this study has identified particular concerns around reduced volume and the progress against jackets, jacket installation vessels, monopile installation vessels, HVDC technology, standardisation of offshore substations and cost reductions from growth and scale. Increased allocation risk (linked to volume) looks likely to limit progress on the cost of equity through increasing the developer risk-premium.

Given the restrictive nature of the Levy Control Framework (LCF) and limited expectation of increased 2020 volume across the EU, the sector should seek to maximise the benefit from the volume available, while taking additional actions to minimise the risk posed to the indicators listed above.

The lack of clarity on the LCF budget in the period after 2020 presents further challenges to developers and the supply chain.

Greater consideration of the balance between innovation and risk

The drive to reduce costs across industry is manifested in a drive to innovate technology. However, this innovation could prevent a fall in the cost of capital, as investors view the unproven nature of new technology as incurring additional risk. Industry needs to continually balance the impact of innovation to drive efficiency and scalability, on financing costs. Investors have stated that they have greater appetite for proven components and processes, and would welcome greater standardisation where possible. In addition, developers should be aware of the total risk profile they present to investors; if a developer does not have a strong balance sheet, other risks should be minimised, for example through fewer contracts, an EPC wrap, best practice installation process or a technology (WTG/cabling/subsea stations) with greater operating experience.

De-risking construction

Construction risk remains problematic for the sector, with the industry continuing to suffer a significant volume of process failures. This is impacting the appetite of equity investors and resulting in no apparent reduction in the level of contingency applied to projects. This presents a strong case for increased activity from institutional investors such as the Green Investment Bank (GIB) and the European Investment Bank (EIB). Investors are keen to see further reductions in the number of contract packages and greater knowledge sharing to demonstrate and embed scalability, reliability and best practice. The lack of progress on standard contracts further increases construction risk.

Potential equity pinch point

A further concern on the cost of equity indicator is the increased demand for equity in response to the large number of projects which are likely to seek financial close over the next two or three years. This is driven by projects seeking to meet RO closure deadlines, deliver under FIDeR and (once the winners are announced) the first CfD allocation round.

Impact of the move to Contracts for Difference

As well as having potential benefits on the sector including heightened cost reduction pressure, the move to the new regulatory regime may impact progress on certain indicators, including the developer risk premium, FEED, supply chain involvement and site investigation.

On the basis of the analysis presented in this report, the following **recommendations** are made:

1. The OWPB should engage with equivalent bodies across Europe to share knowledge and improve the co-ordination of cost reduction initiatives across the wider industry.
2. The OWPB Supply Chain Group should consider what additional actions may be needed to ensure ongoing progress towards £100/MWh can be achieved, given reduced volume projections. This should, in particular, consider the long-term implications of reduced volume on jackets, purpose built installation vessels for (both) jacket and monopile installation, HVDC technology and standardisation of offshore substations.
3. Following the 2015 general election, the OWPB should work with DECC to provide greater clarity on the LCF budget available to fund CfDs in the post-2020 period.
4. The OWPB Finance Group should:
    a. closely monitor the potential risk of a capital shortfall, developing mitigation plans which consider the role of organisations such as the Green Investment Bank (GIB), the European Investment Bank (EIB) and Infrastructure UK (IUK) to increase their involvement in the sector.
    b. seek increased support for construction risk sharing from institutional investors such as the GIB and the EIB, who are able to provide equity during construction, where developers might otherwise struggle to find investment at suitable cost. This is particularly important in the project financing of megadeals (>£1bn)
    c. ensure greater consideration is given by the financial community of the balance between innovation and risk, with greater knowledge sharing to embed scalability, reliability and best practice in offshore construction.
5. The OWPB Contracting Group should:
    a. initiate action towards the development of standard contracts within 2015 to avoid this indicator being rated as 'missed target' next year.
    b. consider specific actions designed to reduce contingencies reserves.
6. OWPB Technology and Innovation Group should ensure:
    a. that following completion of the OWA project on Integrated Design that the principles are carried forward and implemented on a project.
    b. progress is made on wind farm wide control technology.
    c. demonstration sites are secured for Gravity Base Structures (GBS) and 66kV array cables.
    d. Actions are taken to secure investment in specialist jacket and monopile vessels. This should include a review of the potential risk of a vessel supply crunch in 2017, particular in deeper water.

7. The OWPB Grid Group should:

    a. Seek to progress standardisation of AC substations across the sector.

    b. Review the interaction between the OFTO regime and the ability for developers to use dynamic rating of cables and overplanting of generating assets.

Table 1-1 Summary findings and recommendations

Level 1 Indicator	Summary findings	Recommendation
PM and Development	Developers have improved the way in which they design and develop offshore wind farms, with greater involvement of the supply chain, site investigation and prioritisation of the most cost effective sites. Floating LIDAR continues to develop, reaching pre-commercial level in 2014. Going forward, there are concerns regarding the impact of the introduction of CfDs on the design process and developers need to use SI data collected more effectively	The OWPB should consider how introduction of CfDs may adversely affect the design process for wind farms. The OWPB Finance Group should consider how to mitigate this risk.
Turbines	Turbine ratings have increased rapidly, alongside improvements to the drive train, control systems, blade manufacture and design. This has resulted in a significant increase in load factors. The sector is ahead of even the "Technology Acceleration" story of The Crown Estate Pathways Study. Outlook is positive, although poor early performance on the larger machines could slow progress. Need for focus on integrated design and wind farm wide control approaches.	OWPB Technology and Innovation group should ensure that following completion of the OWA project on Integrated Design that the principles are carried forward and implemented on a specific project. OWPB Technology and Innovation group to ensure progress on wind farm wide control
Balance of Plant	All contracts signed in 2014 were for monopile foundations. This trend is expected to continue, with rapid development of XL monopiles and new design standards. Jackets were assessed as 'behind target', with market size and lack of orders a major concern. There is reasonable progress on suction buckets but slow progress on GBS. GBS and 66kV cables need to secure opportunities for demonstration. A joint industry project is needed to ensure continued progress on array cable specs (although this should be considered in terms of overall cost reduction potential)	The OWPB Technology and Innovation group should ensure that demonstration sites are secured for GBS and 66kV cables. (See recommendation under 'Growth and Scale' re impacts of volume projections on jacket design and manufacture)

Level 1 Indicator	Summary findings	Recommendation
OFTO Capex	Experience of HVDC technology in Germany has meant that the industry is looking to extend conventional HVAC solutions to far offshore sites, reducing the potential market for HVDC. DONG have progressed standardised substations but there is little progress elsewhere. First project has been built using overplanting principles. Progress is needed on the interaction between OFTOs and dynamic rating of cables, with developers concerned around insurability, bankability and the assessment of availability.	The OWPB Grid group should seek progress standardisation of AC substations across the rest of the sector The interaction between the OFTO regime and the ability for developers to use dynamic rating of cables and overplanting of generating assets should be reviewed by the OWPB Grid Group.
Installation	There has been rapid improvement in the installation process for turbines and cables. Foundation installation is considered 'on target'. There are concerns over the lack of orders for floating dynamically positioned (DP), purpose-built jacket and monopile installation vessels	OWPB Supply Chain Group should consider what could be done to ensure investment in specialist jacket and monopile vessels is forthcoming.
O&M	There has been rapid development in crew transfer vessels, floatels and access techniques. Condition monitoring is improving and is beginning to be used in O&M scheduling. Further improvement needed. Overall, the sector is demonstrating more of a focus on O&M, although developers will need to develop improved inventory management techniques as projects come out of warranty.	N/A
Design Life	Rapid progress has been seen in design life, with a strong consensus across the industry that projects are now being designed for 25 years (up from 20 years in 2011/12). Little consensus on whether the sector will see any further increase anytime soon; some respondents flagged that tax depreciation issues are a major barrier to further increases.	Indicator has achieved 2020 target already.

Level 1 Indicator	Summary findings	Recommendation
Growth and scale	Growth and scale is assessed as 'behind target', primarily due to volume reductions at an EU level (including UK capacity). This seems unlikely to recover at an EU level before 2020. The UK market was assessed as 'on target', with at least 10GW of projects with reasonable certainty of financial support (across ROCs, FIDeR and the first CfD allocation round). Beyond this, there are a large number of projects which are targeting CfDs and are facing significant allocation risk. The study has found a weaker link to date between volume and cost reduction, with the sector broadly on target, despite volume downgrades in the UK and Germany. This may reflect a short term benefit (from increased competition); in the long run, developers and the supply chain have raised concerns about the long term impact of reduced market demand.	The OWPB should engage with European counterparts as appropriate to maximise volumes and share knowledge to drive down LCOE across the wider industry The OWPB should consider what additional actions may need to be taken to ensure ongoing progress towards £100/MWh can be achieved, given reduced volume projections. This should, in particular, consider the long term implications of reduced volume on jackets, purpose built installation vessels for (both) jacket and monopile installation, HVDC technology and standardisation of offshore substations. Following the election, the OWPB should work with DECC on providing greater certainty post 2020 on LCF budget allocation.
Competition	Mixed, but overall considered 'on target'. Market has seen both entrances and exits from the market. Turbine installation and cable installation are considered 'ahead of target'. Competition in turbines, foundations, HVAC electrical systems and HVAC cables are 'on target', as was foundation installation. Further increases in competition in the turbine market is critical and relies on continued progress of the new joint ventures. Risk of a potential turbine installation vessel supply crunch in 2017, particular for deeper water projects. Unclear what the exit of Technip will do to the cable installation market.	OWPB should review the potential risk of a turbine installation vessel supply crunch in 2017, particular in deeper water.

Level 1 Indicator	Summary findings	Recommendation
Collaboration	Evidence indicates rapid progress on technical standards and guidelines specific to offshore wind, and good progress on development of knowledge sharing frameworks and gradual improvements in supply chain engagement. Urgent need to develop standard contracts. There is a general trend towards a smaller number of contract packages but still diversity in the sector. No strong evidence has been found to indicate that contingencies are reducing. Limited reduction in contingencies may reflect long lead times between introduction of collaborative approaches and developers having the confidence to reduce contingencies on projects.	The OWPB Contracting group should initiate action towards the development of standard contracts within 2015 to avoid this indicator being rated as 'missed target' next year. The OWPB Contracting group to consider whether anything can be done to ensure reduced contingencies on projects
Cost of Equity	This is on target for 2014, with no shortfall in funding and risk premiums on track. There are concerns that this indicator could fall behind target over the next couple of years due to CfD allocation risk increasing the developer risk premium, technology risk from rapid innovation and a potential capital shortfall in 2015/16.	The potential risk of a capital shortfall in 2015/16 should be closely monitored by the OWPB Finance sub-group, with potential for organisations such as GIB, EIB and IUK to step in and help mitigate this risk. Increased support for construction risk sharing from institutional investors such as the Green Investment Bank (GIB) and the European Investment Bank (EIB), who are able to provide equity during construction, where developers might otherwise struggle to find investment at suitable cost. This is particularly important in the project financing of megadeals (>£1bn)
Cost of Debt	Debt margins have reduced to around 275-300 bps and this indicator is ahead of target. There is some indication of appetite for increased gearing, but insufficient evidence to date to enable firm conclusions. Outlook is good.	OWPB to ensure greater consideration of the balance between innovation and risk, with greater knowledge sharing to embed scalability, reliability and best practice in offshore construction. Increased role of Multilaterals and institutional lenders
Insurance	Insurance premiums have fallen ahead of the levels considered within the Pathways Study and are 'on target'. Outlook is good.	N/A

2 INTRODUCTION

The ORE Catapult, in conjunction with The Crown Estate, is developing a Cost Reduction Monitoring Framework (CRMF), on behalf of the Offshore Wind Programme Board and the members of the Offshore Wind Industry Council. The CRMF is designed to track the industry's progress towards a target LCOE of £100/MWh at FID 2020. This is the first year that the scheme has operated and is expected to be repeated in subsequent (Calendar) years

The CRMF has two elements:

- a qualitative scheme being developed by DNV GL, supported by PwC. This is a forward looking scheme tracking leading indicators
- a quantitative scheme being developed by Deloitte. This is backward looking scheme

This report is the summary of the results of the **qualitative element**. It begins with a short overview of the methodology, before discussing the high level results and then providing a broader discussion on the outlook for the sector.

A number of other documents provide background to the design of the scheme and further detail on the assessment process:

- Appendix C, provided in a stand-alone report titled: *113259-UKBR-A CRMF Evidence log*. This report contains all of the evidence collected by DNV GL and PwC to assess progress against the milestones.
- Appendix D, provided in a stand-alone report titled: *CRMF Indicator Tracking Tool - Implementation FINAL.* This spreadsheet provides all of the work undertaken in the design phase, including the approach to assessment of each of the milestones and weightings.
- Appendix E, provided in a stand-alone report titled: *113259-UKBR-R-03-C CRMF Final Design*. This document describes the design of the scheme in detail and should be read in conjunction with the Indicator Tracking Tool.

3 METHODOLOGY

The qualitative element of the CRMF is a bottom up, milestone-based framework which seeks to track progress against 66 indicators from 2011 to 2020. Each indicator is weighted according to its cost reduction potential. The framework draws on and updates the Cost Reduction Pathways Study published by The Crown Estate in 2012.

The scheme has been completed in two phases:

Stage 1 – Design Phase

In the first stage of the project, DNV GL and PwC defined key terms (see Appendix A) and reviewed the Cost Reduction Pathways Study and progress in the sector since then. This led DNV GL and PwC to define the list of indicators to be assessed, target pathway for each indicator, scoring methodology, milestones to be tracked, and the weightings chosen for each indicator. More detail on the design decisions taken is provided in the Final Design Report[1] included as Appendix E.

This design was then reviewed and approved by the CRMF Steering Group and the Offshore Wind Programme Board Risk Committee.

Stage 2 - Implementation

The second stage of the project involved collecting evidence from a broad range of sources to assess the sector's progress against the indicators and milestones defined in Stage 1.

This involved:

- consultation with around 30 companies in the offshore wind sector;
- a literature review;
- internal knowledge capture reviews by DNV GL and PwC.

All of the evidence collected is included in the Evidence Log (Appendix D) and was used to assess progress against each of the milestones.

Key points

When reviewing the results of the qualitative CRMF it is important to note the following:

1. *The analysis is based largely on the Pathways Study* – where possible, DNV GL and PwC have applied the results from the previous work. This is not a full, quantitative cost modelling exercise and as such, the amendments made have been made on the basis of DNV GL and PwC judgement, combined where possible with use of the 'Simple LCOE modelling tool[2]' developed in the Pathways Study and freely available online.
2. *The target pathway out to 2020 for each indicator was based on an assessment of the most relevant Story (Slow Progression, Technology Acceleration, etc) within the Pathways Study.* For instance, on turbine rating, the Technology Acceleration story suggests that in 2014 there should be: 'Some uptake of the first of the next generation of 6MW Class turbines with an increased focus on reliability'; Slow Progression has a similar Story but with a two year aggregate delay. Given that the sector deployed the first 6MW turbines in 2013 (Repower 6M on Thornton Bank), saw the first commercial deployment of the Siemens 6MW in 2014 and that a significant pipeline

[1] 113259-UKBR-R-03-C CRMF Final Design, provided in Appendix E.

[2] Available at: http://www.thecrownestate.co.uk/media/149536/simple_lcoe_model.xlsx

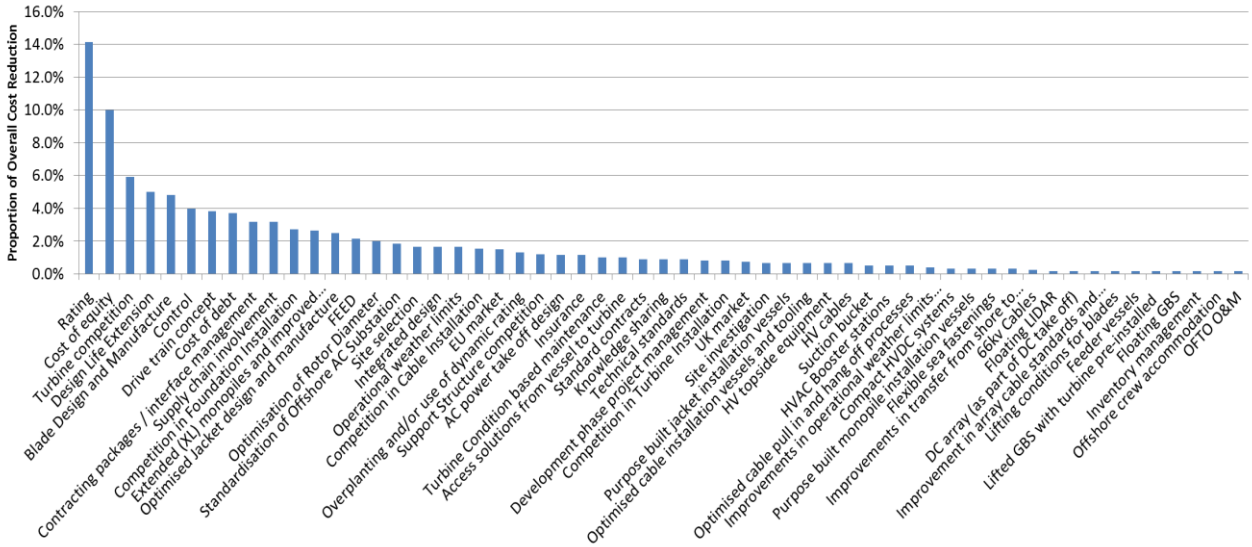
of projects have contracted 6MW turbines, the Technology Acceleration story was determined to be most appropriate for that indicator. This approach was repeated for all indicators.

3. *A hybrid scenario was therefore developed.* This approach was in line with the original strategy of the Pathways Study, where the four industry Stories represented a 'menu of options', representing an overall envelope within which a cost reduction pathway would emerge.

Weightings

The relative weightings used in the study are shown in Figure 3-1 with Table 4-1 providing further detail. As can be seen increase in turbine rating is the largest single cost reduction initiative.

Figure 3-1: Summary graphic showing the relative weighting of the indicators



Consultees

The study had a good response from engagement with developers, financiers and wind turbine and electrical OEMs. However, with one or two exception there was limited engagement from OFTOs, fabricators, contractors, array cable manufacturers and vessel operators. This implies reduced confidence in those indicators relating to installation and fabrication.

4 RESULTS

This section provides a summary discussion of the results. Table 4-1 provides an overview of the CRMF results, with the text providing a summary discussion.

The indicators were derived on the basis of the Pathways Project and DNV GL and PWC experience. Full explanations of the indicators may be found in Appendix C - Evidence Log.

Table 4-1 Overview of indicator ratings

Key	Ahead of target	On target	Behind target	Missed target

Work stream	Level 1	Level 2	Level 3	%[3]
Technology	**PM and Development**		FEED	2.2
			Site selection	1.7
			Site Investigation	0.7
			Development Phase Project Management	0.8
			Floating LIDAR	0.2
	Turbines	Nacelle	Rating	14.1
			Drive train concept	3.8
			AC Power Take off	1.2
		Rotor	Optimisation of rotor diameter	2.0
			Blade design and manufacture	4.8
			Control	4.0
		Integrated design of turbine and support structure		1.7
	Balance of Plant	Cables	66kV	0.2
			DC array	0.2
			Array cable standards and specs	0.2
		Support structure	Monopiles	2.7
			Jackets	2.5
			Suction buckets	0.5
	OFTO Capex	Near/Mid shore	Standardisation of offshore substations	1.8
			Overplanting/Dynamic ratings	1.3
		Far shore	HVDC	0.3
			HVAC Booster stations	0.5
	Installation	Turbines	Lifting conditions for blades	0.2
			Feeder vessels	0.2
		Support structures	Lifted GBS with pre-installed turbine	0.2
			Purpose built monopile installation vessels	0.3
			Operational weather limits	1.7
			Purpose built jacket installation vessels	0.7
			Flexible sea fastenings for jackets	0.3

[3] Proportion of overall cost reduction assumed by the study

Work stream	Level 1	Level 2	Level 3	%[3]
			Buoyant GBS	0.2
		Cables	Optimised cable pull in	0.5
			Improvements in operational weather limits	0.4
			Optimised cable installation vessels and tooling	0.7
	O&M		Condition monitoring based maintenance	1.0
			Access solutions	1.0
			Improvements in transfer from shore to site	0.3
			Inventory management	0.2
			Offshore crew accommodation	0.2
			OFTO O&M	0.2
	Increased design life			5.0
Supply chain	**Growth and scale**	UK 2020 capacity		0.8
		EU 2020 capacity		1.5
	Competition within the industry	Turbines		5.9
		Support Structures		1.2
		Electrical	HV topside	0.7
			HV cables	0.7
		Installation	Turbines	0.8
			Foundations	2.7
			Cables	1.5
	Collaboration	Vertical	Contracting packages/ interface management	3.2
			Supply chain involvement	3.2
		Horizontal	Standard contracts	0.9
			Technical standards	0.9
			Knowledge sharing	0.9
Finance	**Cost of equity**	Capital availability – Construction		10.0
		Capital availability - Operations		
		Regulatory risk premium		
		Construction specific risk premium[4]		
		Operations specific risk premium		
		Developer Risk premiums		
	Cost of debt	Change in gearing - Construction		3.7
		Change in gearing - Operations		
		Construction Debt - margins		
		Operations Debt – margins		
	Insurance	Construction phase		1.1
		Operations phase		

[5] GBS concepts are considered within the installation section as this was considered the primary cost reduction driver for the UK market.

4.1 Development and Project Management

The sector has seen improvement in the way in which it develops projects due to:

- improvements in wind farm design, in part driven by increased supply chain involvement and a greater level of site investigation;
- the introduction of offshore wind-specific management systems at leading developers;
- a greater emphasis on bringing forward the most cost-effective sites; and,
- ongoing commercialisation of Floating LIDAR systems.

This implies that this is indicator is 'on track'.

Looking forward, concerns were raised as to the impact of acute allocation risk on those developers seeking a CfD to fund vital, pre-FID expenditure and in turn optimise the design of projects. This could amplify current concerns from OEMs that although developers are collecting more site data on ground conditions, it often does not come early enough in the process to be used effectively. To ensure continued progress on the Site Investigation indicator next year, developer will need to ensure that any site data collected is used effectively in the design process.

4.2 Turbines

Progress on turbines has been more rapid than even the Technology Acceleration story assumed and is therefore considered: 'ahead of target'.

Increase in turbine rating offers the largest cost reduction potential of any initiative and was rated 'ahead of target'. This was due to the first commercial deployment of 6MW unit by Senvion in 2013 and signing of a 1.8GW framework agreement in the UK between DONG and Siemens for the SWT-6.0-154, with the first project from this agreement (Westermost Rough) entering construction this year. MHI Vestas signed a conditional order with DONG for the first commercial deployment of the 8MW164; if this closes by the end of this year end as expected, it will imply the sector is three years ahead of the Technology Acceleration story. Other OEMs installed prototypes including: ALSTOM (6MW, offshore), Samsung (7MW, offshore), MHI Vestas SeaAngel (7MW, onshore and by year end offshore in Japan on a floating, semi-sub tripod), Ming Yang (2 bladed 6.5MW, offshore). Progress on turbines with nameplate capacities over 9 MW is underway, with Siemens announcing that they expect to have a 10MW unit available towards the end of the decade.

Many of these turbines offer substantial innovations in drive train, with the Siemens 6MW 154 the first commercial deployment of a direct drive unit offshore and the MHI Vestas 7MW SeaAngel featuring an innovative hydraulic drive train. OEMs continue to increase rotor diameters to drive greater AEP, while the sector is seeing ongoing improvements to control systems and rapid improvements in blade design and manufacture. Relatively little progress has been made on integrated design, though The Carbon Trust has launched an ITT on this subject through the Offshore Wind Accelerator.

Given the rapid technical progress there are clear risks that these new larger turbines will struggle as they move into serial production, reflecting the trade-off between innovation and risk. Small demo sites (5 turbines) may also be in short supply. This has not been an issue to date, as demonstrated by MHI Vestas having secured a commercial order without an offshore prototype installed. However, this is considered a special case (reflecting technical competence of MHI Vestas and DONG's strategic interest in improving competition in the turbine supply market). Other OEMs may need a small demonstration site to prove zero series turbines. In terms of control, the sector needs to begin testing wind farm wide control systems next year to ensure this indicator remains on track.

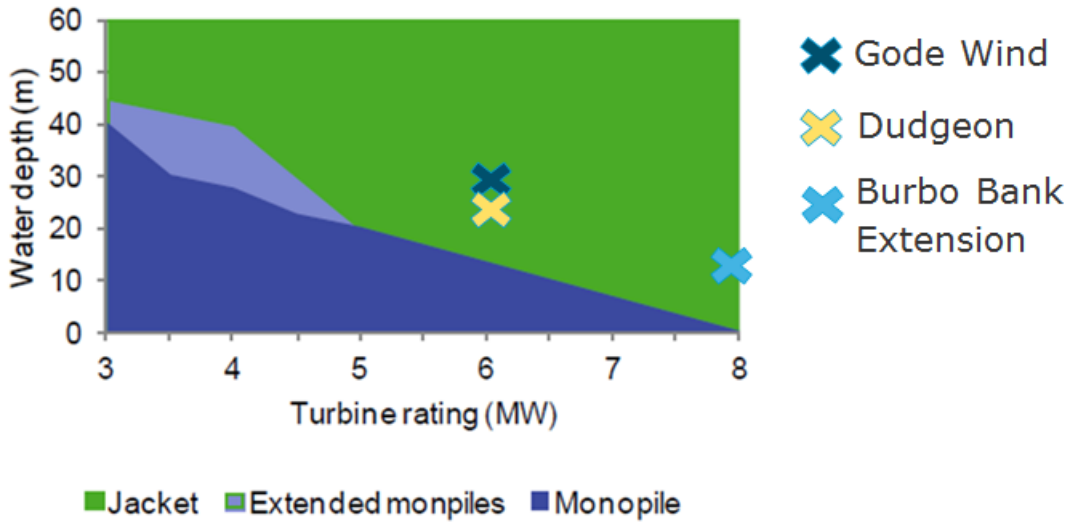
4.3 Balance of Plant[5]

Overall, balance of plant is assessed as being 'on target'. However, this conclusion should be considered alongside significant variation in the progress of the various level 3 indicators.

Since the Pathways Study, the industry has seen a significant shift in terms of rapid development of XL monopiles, allowing deployment with bigger turbines and in deeper water. Figure 4-1 comes from the Technology work stream report of the Pathways Study and shows how recent projects have pushed the limits in regards to monopile technology. This was reflected within the design phase of the CRMF, with monopiles having a higher weighting and much more challenging pathway.

Against this more challenging pathway, this indicator was rated as 'on target' with FID on 7m+ monopiles at Dudgeon and Gode Wind, improvements in design standards and joint industry projects such as SLIC and PISA[6]. Further improvement is expected, with a broad consensus from interviewees that up to 10m monopiles will be achievable in the next few years, although some installation challenges remain. Supply chain and installation issues of larger monopiles will need to be resolved to ensure continued progress on this indicator.

Figure 4-1 Water depth and turbine rating of monopiles recently or expected to be contracted overlaid onto graphic from the Pathways Study[7]



The rapid development in XL monopiles has resulted in more challenging progress for jackets and as such this indicator is behind target, with the industry struggling to move to serial production methods. The lack of orders appears to be the primary reason for the slow progress, with no jacket orders closing in 2014. Without orders, it seems unlikely that fabricators will have the confidence to invest in a purpose built jacket manufacturing facility needed to more this indicator forward.

Suction buckets were rated as 'on target' having developed rapidly over the past two years, with the first full scale demo unit installed in Germany and a number of developers considering the concept. It remains to be seen whether any project will have the confidence to contract using this technology in the next two years.

[5] GBS concepts are considered within the installation section as this was considered the primary cost reduction driver for the UK market.
[6] SLIC is Offshore Wind Structural Lifecycle Industry Collaboration. PISA is Pile Soil Analysis Project
[7] Initial graphic is © BVG Associates

Array cables were assessed as being behind target, with the sector taking longer than expected to move towards 66kV cables. This appears to be driven by relative marginal economic benefit of doing so, in part driven by an immature supply chain for this component, alongside the perceived risk, with no developer wanting to make the first move. This indicator appears likely to remain behind target. DC arrays was the only indicator assessed as 'missed target' with a reasonable consensus that this technology will not be deployed on projects by 2020.

There has been some improvement in the way in which array cables are specified, with leading developers moving to higher ratings (34kV) and initial guidance published on array cable specifications. A joint industry project on array cables specifications and standards is needed to ensure progress in this area next year (although this needs to be considered in the context of the limited cost reduction potential associated with this indicator).

4.4 OFTO Capex

Progress on the OFTO Capex element (or transmission infrastructure) has been assessed as 'on target', though again this masks significant variation within level 3 indicators.

The most notable change since the Pathways Study has been the move away from HVDC solutions, towards HVAC. This change has been driven by experience of the technology in Germany, which has seen significant increases in cost and substantial delays. HVDC is therefore considered 'behind target'. Looking forward, the focus on cheaper sites and potential concerns around the compatibility of HVDC and the timescales laid down for delivery under CfDs may mean that no UK project contracts using HVDC technology by 2020.

Due to the increasing cost of HVDC, reactive compensation 'booster stations' have emerged as a potential alternative for far-shore wind farms. There appear to be no technical barriers to this, with the decision purely as to whether it is more cost effective. This indicator was therefore considered 'on target'.

For nearer shore wind farms, DONG have clearly led the way in regards to standardising offshore substations, having developed a standard wind farm concept and a common substation design for five substations across 3 wind farms. Other developers have made little progress on standardisation, citing the lack of a project pipeline as the major barrier. Overall, this element was considered as 'behind target' (representing the lack of progress across the wider industry).

Good progress appears to have been made to date on overplanting and dynamic rating of cables, with one project in the UK already constructed with an oversized generating capacity compared to export infrastructure. Many developers are considering dynamic rating of cables. The major barrier to both initiatives appears to be interactions with the OFTO regime, with developers citing concerns around the assessment of availability if rated below capacity, effect of introducing curtailment relating to enhanced temperature monitoring, insurability and bankability. One developer noted the need for a standard for dynamic ratings. Whether overplanting will be allowed under the Contract for Difference (CfD) regime deserves further investigation and clarification.

4.5 Installation

Progress in the installation phase has been assessed as 'on target', with variable degrees of progress across the installation process for turbines, foundations and cables.

On the turbine side, the sector has seen rapid progress in terms of blade installation, with most developers suggesting that 12m/s is achievable, while Siemens is claiming that blades can be installed up to 14m/s. 12m/s was the level expected within the Pathways Study in 2020, suggesting the sector is

well ahead of target. Developers are also considering fast feeder vessels, although there are different views as to the effectiveness such measures.

Cable installation has been assessed as ahead of target, due to innovation in cable pull in and hang off design, new trenching and ploughing tools and the commissioning of new cable installation vessels.. Skills were flagged as a concern in cable installation and it was not clear what the exit of Technip would do to this market.

The picture on foundations was more mixed, with the sector ahead of target in terms of weather limits for monopile installation, yet behind target in terms of purpose built monopile installation vessels and the sector continuing to use a mix of heavy lift vessels and wind turbine installation vessels. Developers flagged the need for new purpose built monopile installation vessels. It is not clear that there will be sufficient market for this to happen, given volume downgrades and that there is not a clear gap, with the business case based on marginal efficiencies over the current fleet of heavy lift vessels (as opposed to an absence of technical capability).

Jacket installation was on target for this year in terms of the number of jackets that vessels can carry and install (although this is driven by the turbine installation market as opposed to specialist jacket installation vessels). However it seems likely that this indicator will fall behind target in 2015 and 2016 with no vessels currently on order than could carry and install 6 jackets. The sector is also behind target on flexible sea fastenings for jackets. The reduced expectation of market demand for jackets appears to be the primary barrier and it seems unlikely that there will be rapid progress in this indicator going forward.

GBS (both floated and lifted with a pre-installed turbine) were assessed as 'behind target', with ongoing work but no demonstration sites secured to test more novel concepts. DNV GL suggest that given the challenges of securing a demo site, combined with high mobilisation costs, may mean that these concepts attempt to move straight to commercial scale projects. It is not clear whether this will be financeable though.

4.6 Operations & Maintenance (O&M)

Progress in operations and maintenance has been scored 'ahead of target'. This is due to rapid improvements in crew transfer vessels and emergence of the first use of floatels and Offshore Support Vessels. The sector is seeing improvements in access techniques and condition monitoring of turbines and this data is starting to be used to determine O&M activities.

OEMs have sophisticated inventory management techniques which mean that this indicator is assessed as being 'on target' now. However, as more wind farms come out of warranty, developers will need to develop competence in this area.

Although research saw relatively little engagement with OFTOs, DNV GL is aware that OFTOs are considering options for reducing O&M costs for the electrical element (through call off contracts for cable repair, condition monitoring and ability to flex warranties), although there is limited progress on the ground. Progress is needed on condition monitoring next year.

Looking forward, the move to larger, more reliable turbines is expected to have the most significant impact on O&M costs (although this benefit is covered in the turbine indicator).

4.7 Design life

Almost all developers are now working on the basis of a 25 years design life and considering turbines that are certified to this level. This represents rapid improvement from the 20 years baseline in the

Pathways Study and the expectation of 25 years to be achieved in 2020. This indicator is therefore well ahead of target.

There is little consensus on whether the sector will see any further increase anytime soon; some respondents flagged that tax depreciation issues are a major barrier to further increases.

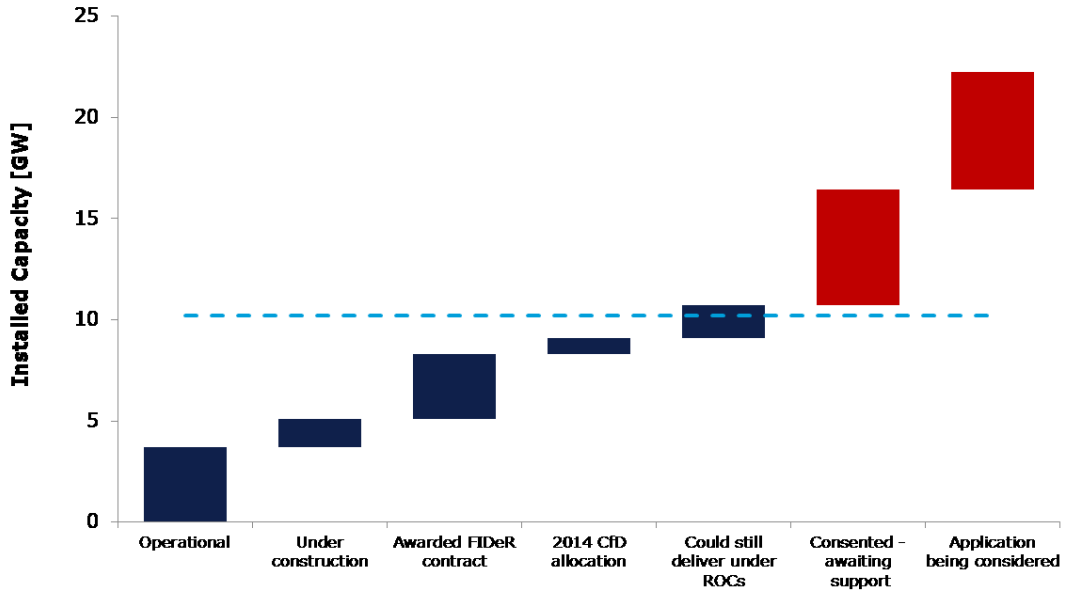
4.8 Growth and scale

DNV GL has concluded that this indicator is 'behind target'. Perhaps controversially, this conclusion is derived from an 'on target' assessment for the UK market, and a 'behind target' assessment for the EU market. It is important to note that the weighting associated with this indicator has been reduced substantially (from the Pathways Project) to reflect the reduced cost reduction potential assumed in a smaller market.

Both of these assessments are based on assumptions on the capacity expected to be deployed by 2020.

In the UK market, the milestones were drafted on the basis of the latest information from Electricity Market Reform (EMR), with National Grid's 'best guess'[8] of 2020 capacity taken as the baseline. The on target milestones for 2014 was therefore defined as a: '*Clear pipeline of projects able to deliver at least 10GW by 2020, with reasonable certainty of financial support.'* DNV GL concludes that, with existing capacity operational or under construction, FIDeR projects, projects which could go for ROCs and the budget allocated in the first allocation round, a pipeline of at least 10GW does exist. This however assumes that at least 1GW of projects utilise ROC grace periods, with Race Bank and Rampion well positioned..

Figure 4-2 UK Development pipeline



Clearly, beyond this pipeline there are a very large number of projects seeking CfDs in this first, and any subsequent, allocation round. These projects are facing significant uncertainty and acute allocation risk.

[8] Scenario 1 in: 'National Grid EMR Analytical Report', published December 2013 as Annex D of 'EMR Delivery Plan' (Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/267614/Annex_D_-_National_Grid_EMR_Report.pdf)

This was cited by a large number of respondents as the primary barrier to cost reduction, with an expectation of further attrition if further certainty is not provided.

In the EU, the 'on target' milestone was defined as: 'between 7 and 8GW installed with an expectation of 25GW by 2020. 2030 EU target is set'. The sector has met two of these requirements, having installed 7.5MW in commissioned projects and with the 2030 EU-wide target set (although this is non-binding at a national level). However, the latest projections from EWEA predict 23.5GW installed in their 'medium' scenario. This milestone was therefore considered 'behind target'. It seems unlikely that this indicator will recover.

As the supply chain considers the market to be a European one (as opposed to UK specific) the EU market was considered more important than the UK market for cost reduction, the overall result was 'behind target'.

4.9 Competition

Competition across the sector has been assessed as 'on target', with a large number of entrants to, and exits from the market. The overall positive score reflects reductions in market volume in the UK and Germany increasing competitive pressures.

Turbines

Competition in turbine supply has been assessed as 'on target'. This is because there are four OEMs who have proven turbines in the market (Senvion, Siemens, MHI Vestas, Areva), yet only Senvion and possibly Siemens have proven turbines in the 6MW+ category.

Siemens remains the market leader – it has picked up all of the firm orders completed in 2014 and has secured a sizable framework contract with DONG. Joint ventures from leading players suggest that competition is set to improve. These include:

- MHI Vestas
- Areva Gamesa
- ALSTOM GE

Of these, MHI Vestas picked up their first conditional order and announced that they were establishing blade production facilities (subject to orders) on the Isle of Wight[9]. ALSTOM installed an offshore prototype and are currently building factories in France for the serial production of the Halidade turbine. ALSTOM and Areva have also picked up a number of orders in France which should allow them to gain significant operational experience. Chinese players are active but there is no indication to date that they may be able to break into the European market. Competition in the turbine market was therefore considered 'on target'. Progress on this indicator in future relies on continued progress of the new joint ventures and smooth introduction of the larger turbines.

In terms of the UK, developers noted that the push towards a UK supply chain may reduce the amount of competition in the market.

Balance of plant

[9] Available at: http://www.mhivestasoffshore.com/media-and-news/news/2014/12-10-2014 Accessed on 20/11/2014

In support structures, developers suggested there was reasonably good competition in the market, with around 3-5 suppliers with a strong track record and capability of delivering XL monopiles. A similar number of suppliers appear to have a track record in the serial production of jackets, although others have credible investment plans. Suppliers from Asia do exist but to date EU countries have dominated. This indicator was therefore assessed as 'on target'.

OFTO Capex

On AC substation topsides[10] developers noted that there were around 3-5 suppliers in the market, with competition generally rated as 'very limited' or 'some competition but with clear market leader'. CG Systems have entered the market since the Pathways Study and so this indicator was scored as 'on target'.

Competition in HVAC cables[11] was considered 'on target' with a number of new entrants moving into the market (NSW, Hellenic), expansion of production facilities and over 5 suppliers active in the market. Developers however suggested that there was only 'some competition in the market', with risks of long lead times. The number of suppliers in the market does not appear to translate into strong competition. This may in part reflect previous anti-competitive behaviour by suppliers[12] and differences in supply at different voltage levels, with reasonable competition up to around 150kV, but less for the higher voltages.

Installation

DNV GL suggests that there are over 15 wind turbine installation vessels (WTIV) active in the market. The majority of these are new build vessels that have moved the market away from the chronic supply shortages experienced around 2011. However, this apparent excess of supply does not seem to have translated into optimism from developers regarding competition in the market, with many noting that a much smaller number of vessels were available. This appears to be driven by the depth of water, with fewer vessels capable of working in 40-50m, and concerns of a supply crunch around 2017-2020. Despite this, this indicator was rated as 'ahead of target', but with an uncertain outlook.

Competition in the foundation installation market was rated as 'on target' with over 15 WTIV capable of installing foundations and around 5 heavy lift vessels (and broader number of vessels including sheer leg crane vessels that can compete). A developer noted that there needs to be further investment in this area but this appears unlikely to be forthcoming (Section 4.5). Competition in the cable installation market is rated 'ahead of target' with a large number of potential vessels and a broad consensus that competition was reasonably good. It is not clear whether the exit of Technip will have a significant impact on this going forward and competence and financial strength of organisations may continue to be a problem going forward

4.10 Collaboration

Industry collaboration is assessed as being 'on target'.

Vertical collaboration (between developers and their suppliers) is assessed as 'on target' (just), with increasing supply chain involvement in the design phase. Although there remains a wide variety of contracting approaches, Gemini closed this year with 2 contract packages and there is a general trend towards a smaller number of packages. However, there is no indication that contingencies are reducing and as such this indicator was assessed as 'behind target'. The lack of progress on contingencies may

[10] Competition in the HVDC market was not reviewed due to the small market share expected in the UK.

[11] Competition in the HVDC market was not considered due to small market share. Supply is known to be an issue in this market given technical challenges and overlap with interconnector market.

[12] European Commission press release – available at: http://europa.eu/rapid/press-release_IP-14-358_en.htm. Accessed on 11/12/2014

reflect the long lead times between successfully deliver of a project and the ability to reduce contingencies on the next. This is particularly problematic given the lack of project pipeline for some developers.

Horizontal collaboration (across tiers within the supply chain) has seen rapid development of offshore wind-specific technical standards and guidelines, good progress in the development of knowledge sharing frameworks but very limited progress on standard contracts. Without progress on this latter area in the next year or so, the 2020 target is likely to be missed for this indicator.

4.11 Cost of equity

Evidence from the interviews indicates that the cost of equity is on target for 2014, but could fall behind target over the next two years.

Interviews with stakeholders from the sector indicated that many of the Level 3 indicators that inform the Level 1 Cost of Equity indicator are on track. In particular, there was a common view held by both developers and respondents from financial intuitions that there was no shortage of equity in the market for projects reaching FID in the next 24 months. A number of developers indicated that interest had been expressed by several investors who had no previous experience in the sector, although typically those investors with previous sector experience showed greater interest and commitment as discussions progressed.

The other common view held by developers was that the change in the support mechanism from the renewables obligation to the CfD has led to greater uncertainty. However, allocation uncertainty does not affect projects that reached FID in 2014 (having secured support under FIDeR or the RO) and so this indicator was assessed as being 'on target' for 2014.

Looking forward, allocation risk is expected to be reflected in higher developer premiums for projects reaching FID from 2015.

In addition, financial institutions and potential equity investors have reservations regarding the balance between innovation and certainty/risk within the sector, with rapid innovation making it difficult to develop proven performance. This means that the construction and operations specific risk premiums are not likely to fall in line with assumptions within the Pathways Study. This means that in 2015, and 2016, these indicators are likely to fall behind target.

4.12 Cost of debt

Despite the introduction of Basel III and liquidity coverage ratios for banks, respondents held the common view that there appears to be sufficient liquidity within the debt market. Quantitative easing has resulted in there being a wall of money enabling projects to access debt, providing the borrowers and sponsors meet the lenders risk criteria. One financial institution suggested that some European markets may even see a step up in liquidity in the next 12 months but without further evidence, could not confirm whether the same would be true in the UK.

As a result of the availability of capital within the market and the limited number of projects pursuing debt finance, the debt margins on loans to projects in construction and operation have reduced to below the levels in the 2012 milestones. In particular, estimates of debt margins for construction projects range from 275bps to 300bps against the previous milestone targets of 350bps for projects reaching FID between and 2014 and 2016. Although beneficial for the sector this reduction is largely due to broader trends and risk premiums associated with offshore projects had not reduced.

The study was less conclusive in determining whether projects approaching FID from 2014 to 2016 will be able to take on higher levels of gearing than is currently assumed within the milestones. Banks indicated that they typically operate with up to 70% gearing. The cost of debt indicator is an assumed weighted average across all projects reaching FID. There has been some evidence of investors achieving gearing of 70% on refinancing of their equity shares in project[13]. However when averaged out over the the sector, actual gearing levels remain low and there is little evidence to suggest that they have increased above the Pathways milestones. For this reason, we have assumed that gearing levels will remain 'on target' for projects reaching FID in the next three years.

As projects have typically been developed by utilities and financed from their balance sheets, the cost of debt makes up only a small proportion of the overall cost of capital for the project.

4.13 Insurance premiums

The offshore wind sector has seen a reduction in both construction and operations insurance premiums despite the relatively high number of claims still being made by developers.

The absolute level of offshore wind premiums will depend on the total capex for the project and the annual revenues that the project is expected to accrue. In addition, operations premiums are expected to be a function of the level of deductible that the operator is willing to take on.

Responses from the interviews indicated that construction premiums are typically in the region of 0.55%-0.75% of capex for property damage only, and would increase by an additional 3.5% of annual revenue if the developer wanted the premium to include delay in start-up. Based on a capex assumption of £3.0m/MW and 3,200FLH, this equates to a range of £16.5-£22.5k/MW for property damage only and increases to between £33.3 and £39.3k/MW/a including delay in start-up for a project reaching FID in 2014. Although premiums are tracking below the 2012 Pathways milestone of £40k/MW/a, the sensitivity of offshore costs to construction premiums means that the cost of insurance remains on target for projects reaching FID between 2014 and 2016.

Indicators for the operations premiums show a more positive picture in relation to the 2012 milestones. Responses to the interviews estimated that insurance premiums for operations projects varied between 0.1% and 0.35% of capex for property damage and 1.25% and 1.75% of annual revenue for business interruptions. Using the same assumptions as above and assuming that projects employ premiums covering damage to plant and loss of revenues, this equates to between £9.0k/MW/a and £18.9k/MW/a. Taking the median value of £14k/MW/a for projects reaching FID in 2014, this would indicate that insurance premiums for operational projects are ahead of target.

[13] As with the case of GIB and Marubeni who in August 2014 raised £370m debt to refinance their 50% share in Dong's Westermost Rough project, bought in May 2014 for £500m (GIB website).

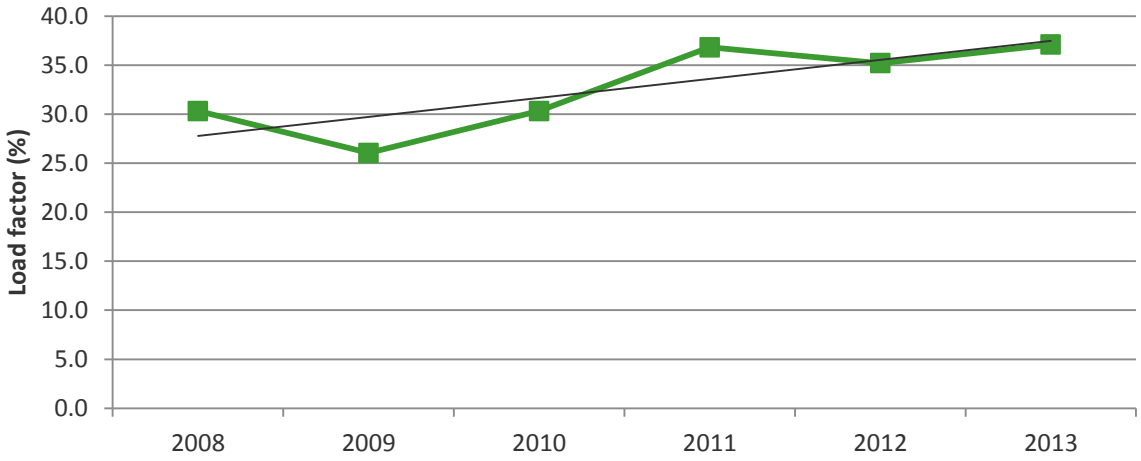
5 SUMMARY OF PROGRESS TO DATE

Overall, the results of this work appear positive, with the industry broadly on target to hitting the £100/MWh target. However, substantial risks and challenges remain.

The positive progress is primarily driven by rapid technological development, with the sector ahead of even the Technology Acceleration story in the Pathways Study in many areas. The turbines are at the forefront of this, with rapid upscaling (the single largest cost reduction opportunity) going alongside increases in rotor diameter and improvements in the drive train, control, condition monitoring and blade design and manufacture. FID has been reached on new manufacturing facilities offering further potential for cost savings.

The improvements in turbines help deliver higher annual energy production, with Figure 5-1 showing increases in load factors across the UK's offshore wind fleet. Looking forward this trend looks set to continue; DNV GL is aware of more recently installed projects in the UK delivering load factors in the high 40's. This is in the context of national windiness in the past two years trending close to normal.

Figure 5-1 Trends in the UK offshore wind fleet-wide load factors (data from DUKES)



Progress has also been made beyond the turbines, with the sector already achieving the 2020 vision in two indicators. The first is design life (which has a significant impact on LCOE), with a broad consensus across the industry that the design life is now 25 years, up from 20 years in the Pathway Study. The second is blade installation, where the sector appears to have moved from a limit of 8m/s in 2012 to 12m/s and above at present.

XL monopiles have developed rapidly and the sector is already contracting monopiles in depths and with turbine options that were previously considered unachievable by 2020. Work on design standards looks set to further reduce the cost. Cabling, traditionally a challenging area for the sector, has also been an area of significant focus.

There have been areas where progress has been slower than expected, with jackets and HVDC technology the most obvious elements. It is worth noting though that these are not standalone items; instead they are in competition with monopiles and HVAC solutions respectively. This implies that progress in this area has not yet caused the sector to grind to a halt, instead they have struggled because other solutions have been favoured (in some cases due to unexpected progress in these areas). The reductions in volume by 2020 and competitive support allocation for CfDs has also meant that shallower, closer to shore projects are likely to be developed, reducing market share for these concepts. In the longer term, improvements will need to be delivered for these items. This is a challenge given reduced volume expectations.

Progress on the supply chain elements has been more mixed. Growth and scale has been assessed as behind target. Against this, competition has been rated on target, with increased competitive pressures as a result of lower market demand. The topic of collaboration is less clear-cut with good progress on technical standards but very limited progress on standard contracts.

Finance is assessed as being on target, with reductions in the cost of debt and insurance premiums being on target. The cost of equity is on target for this year, with no apparent shortfalls in funding at present. Capital recycling remains important particularly given the changing market environment and continued pressure on developer's balance sheets.

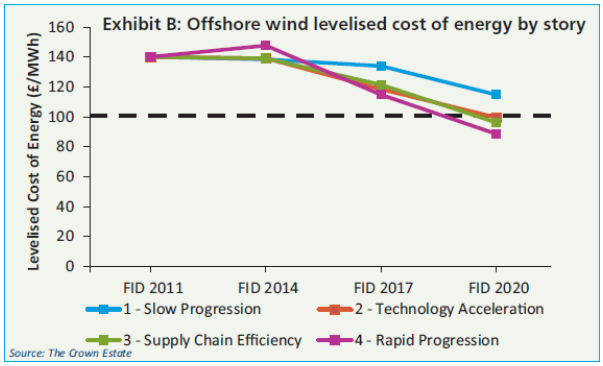
Looking forward, finding investment partners willing to assume construction risk is a challenge, particularly given rapid technical innovation, and could become more pertinent as utilities, who have typically financed projects from their balance sheets, look for investment at construction. The large number of projects seeking FID in next two or three years could create an equity pinch point. For those chasing CfDs, the high allocation risk appears likely to increase the developer risk premium and in turn the cost of equity, with investors reluctant to engage with developers who have not secured a CfD. On the insurance side, the insufficient track record of successful commissioning and operations of new generation WTGs could also limit any further reductions in insurance premiums. The sector therefore needs to strike a balance between innovation and risk.

5.1 Progress against the Pathways Study

As Figure 5-2 shows, the Pathways Study suggested that there would be relatively little reduction in LCOE by 2014, in the Slow Progression, Technology Acceleration and Supply Chain Efficiency stories.[14] The evidence collected in this study, suggests that the sector is broadly on target with this Pathway to date, implying relatively little reduction from the £140/MWh baseline.

Looking forward, the Pathways Study predicted rapid cost reduction between 2014 and 2017 in the Technology Acceleration and Supply Chain Efficiency stories with higher volumes (18GW in the UK), while limited progress on the Slow Progression story (12GW in the UK). The challenge for the industry is to achieve the rapid reductions, but on the basis of reduced volume projections. So far the sector has managed to achieve the reductions required, despite reduced volume, but it remains to be seen whether this can continue. Consideration is therefore needed of how to obtain the maximum cost reduction value from the volume there is across the UK and Europe.

Figure 5-2 Offshore Wind levelised cost of energy by story (from the Pathways Study)



[14] The Rapid Growth story expected an increase in costs but this is ignored due to unrealistic volume assumptions.

6 OUTLOOK

6.1 Introduction

Having shown that the sector is broadly on target, this section looks forward, providing an outlook for the sector as a whole. A bottom up approach is taken, first considering risks and actions required to ensure progress at the Level 3 indicators and then considering broader themes and challenges. The section closes with recommendations.

6.2 Risks to progress at an indicator level

Table 6-1 provides an assessment of the actions required for each indicator to progress next year, based on the milestones developed during the design phase. Considering the actions required and progress to date, a high level assessment of the likelihood of progress for each indicator is provided through colour coding. A green box reflects good likelihood of progress against the indicator next year, a yellow colour suggests an uncertain outlook or need to undertake action, while red suggests low likelihood of progress or limited opportunity to address.

Table 6-1 Actions required and high level assessment of future progress for each indicator

Work stream	Level 1	Level 2	Level 3	%[15]	Actions Required	Likelihood of progress
Technology	**PM and Development**		FEED	2.2	OWPB to review how CfD allocation risk could negatively impact design process	
			Site selection	1.7	Continued focus on cheapest sites	
			Site Investigation	0.7	Data needs to start being used effectively in supplier designs	
			Development Phase Project Management	0.8	Developers to introduce offshore wind specific systems	
			Floating LIDAR	0.2	Continued progress	
	Turbines[16]	Nacelle	Rating	14.1	Smooth introduction of new turbines and ongoing development of larger units	
			Drive train concept	3.8		
			AC Power Take off	1.2		
		Rotor	Optimisation of rotor diameter	2.0		
			Blade design and manufacture	4.8		
			Control	4.0	Need to move towards wind farm wide control	
		Integrated design of turbine and support structure		1.7	Project will need to contract using principles next year (following OWA study)	
	Balance of Plant[17]	Cables	66kV	0.2	Demo site required	Low expectation of FID next year
			DC array	0.2	Remove from study next year	Not considered technically feasible

[15] Proportion of overall reductions captured by these indicators (as opposed to LCOE reduction) i.e. increase in turbine rating is 12.8% of all of the reductions assessed in this study.

16 The impact of developments affecting reliability shall be taken into account – including the impact on energy yield as well as direct cost.

[17] GBS is covered in installation as these is considered to be the primary cost reduction opportunity

Work stream	Level 1	Level 2	Level 3	%[15]	Actions Required	Likelihood of progress
			Array cable standards and specs	0.2	Joint industry project on array cable specs to begin next year	
		Support structure	Monopiles[18]	2.7	Need project to contract 8m monopiles next year	
			Jackets	2.5	Need for additional FID on purpose built manufacturing facility, using standard pipes, etc	Limited volume
			Suction buckets	0.5	Project needs to contract using technology by 2016	
	OFTO Capex	Near/Mid shore	Standardisation of offshore substations	1.8	OWPB Grid group to drive forward improvement in the rest of the industry	
			Overplanting/ Dynamic ratings	1.3	Interactions with OFTO regime is a barrier	
		Far shore	HVDC	0.3	Cost reduction	Limited volume and introduction of CfDs (competition & deployment timescales)
			HVAC Booster stations	0.5	First project needs to contract in 2016	
	Installation	Turbines	Lifting conditions for blades	0.2	2020 target already met	
			Feeder vessels	0.2	First vessel needs to be ordered by 2016	
		Support structures	Lifted GBS with pre-installed turbine	0.2	Needs progress on demo sites	
			Purpose built monopile installation vessels	0.3	Need investment in new, floating purpose built installation vessels	
			Operational weather limits	1.7	Continued improvement	
			Purpose built jacket installation vessels	0.7	New investment in larger vessels	Limited volume
			Flexible sea fastenings for jackets	0.3	Investment in new vessels	Limited volume
			Buoyant GBS	0.2	Needs progress on demo sites	
		Cables	Optimised cable pull in and hang off processes	0.5	Refinement and development of tools and hang off approaches	
			Improvements in operational weather limits	0.4	Continued improvement	
			Optimised cable installation vessels and tooling	0.7	New vessels and tools continue to be developed	

[18] Note that the support structure level 3 items are options rather than necessary components. This table refers to industry progress as a whole, rather than describing a single, 'ideal' 2020 offshore wind farm. This also applies ot to the OFTO Capex indicator

Work stream	Level 1	Level 2	Level 3	%[15]	Actions Required	Likelihood of progress
	O&M		Condition monitoring based maintenance	1.0	Greater integration of data and use within O&m activities	
			Access solutions	1.0	Continued improvement and development	
			Improvements in transfer from shore to site	0.3	Continued improvement and development	
			Inventory management	0.2	Need for focus from developers as projects come out of warranty	
			Offshore crew accommodation	0.2	Vessels with launch and recover capability need ordering next year	
			OFTO O&M	0.2	Need for enhanced condition monitoring	
	Increased design life			**4.5**	5.0	
Supply chain	**Growth and scale**	UK 2020 capacity		0.8	Limited attrition and need for further budget to be allocated under CfDs	
		EU 2020 capacity		1.5	Increase in 2020 expectations to 25GW across EU	Volume expectations unlikely to increase
	Competition within the industry	Turbines		5.9	Continued progress of JVs	Further consolidation is a risk
		Support Structures		1.2	Need for low cost (Asian) competitors	
		Electrical	HV topside	0.7	Developers seeking to bring in new entrant	
			HV cables	0.7	Improvement at higher voltages	
		Installation	Turbines	0.8	OWPB supply chain group to review potential supply crunch in 2017	Concern over supply crunch around 2017, especially for deeper water
			Foundations	2.7	3 new HLV to be ordered	Volume concerns
			Cables	1.5	New build vessels to be ordered	Unclear what exit of Technip will do.
	Collaboration	Vertical	Contracting packages/ interface management	3.2	Further reduction in number of packages and need for contingencies to start reducing	
			Supply chain involvement	3.2	Further improvement in supply chain engagement	CfD allocation risk could impact this
		Horizontal	Standard contracts	0.9	OWPB Contracting group to initiate activity	Appears to be limited appetite
			Knowledge Sharing	0.9	2 KSF to enter mature phase	
			Technical Standards	0.9	At least 4 more guidelines under development	

Work stream	Level 1	Level 2	Level 3	%[15]	Actions Required	Likelihood of progress
Finance	**Cost of equity**	Capital availability – Construction		10.0 (at cost of equity level)	OWPB to monitor potential risk of capital shortfall in 2015/16. GIB & ML to take active role, particularly construction risk	Potential pinch point due to glut of projects seeking funds RO, CfD, FIDeR
		Capital availability – Operations			GIB operations fund to go live and continued recycling of projects	
		Regulatory risk premium			Smooth introduction of CfDs	
		Construction specific risk premium[19]			Greater knowledge sharing and development best practice	Increased risk from new technology
		Operations specific risk premium			Need for demonstrable track record	Balance of innovation and risk
		Developer Risk premiums			Allocation risk under CfDs	Strict LCF budget
	Cost of debt	Change in gearing – Construction		3.7 (at cost of debt level)	Improve visibility to lenders	
		Change in gearing – Operations			Continued progress	
		Construction Debt – margins			De-risk construction phase Increased role of ML	
		Operations Debt – margins			Increased role of institutional lenders	
	Insurance	Construction phase		1.1	De-risk construction phase	
		Operations phase				

6.3 Key risks

The sector faces a number of key risks to future progress:

Volume out to 2020

The cost reduction pathways predicted in the various stories within the Pathways Study were largely independent of volume out to 2014, but then diverged out to 2017 and beyond. The analysis within the CRMF concurs with this, with the sector on track, even with growth and scale tracking behind target.

Looking forward, the relationship between volume and cost reduction is not clear cut.

On the one hand, reduced volumes appear to have increased competition amongst suppliers and there is less risk of supply shortages. The ongoing consolidation should mean that the most competent players survive and provided there is a reasonable pipeline then investment should continue. The most challenging (and expensive) sites have been pulled by developers, aiding cost reduction efforts, while on the finance side, predicted capital shortfalls have not yet emerged (although there is some concern around a 2015/16 crunch).

On the other hand, consolidation could go too far, limiting competition, specialisation and reducing confidence in the market. Concerns over volume (closely linked to CfD allocation risk) may also mean that more developers pull out, impacting the ability of the sector to continue momentum into the 2020's

[19] This indicator seeks to cover the lack of certainty over project execution costs within the installation phase

and reducing competitive pressure in the auction process. Reduced volume appears to be especially problematic for those technologies which the market was expected to move towards (jackets, HVDC) but instead the sector have extended the reach of conventional solutions such as monopiles and HVAC. Volume also appears to be impacting purpose built monopile installation vessels, standardisation of offshore substations and the growth and scale indicator. It is not clear what can be done to try and improve progress on jackets and HVDC in the absence of orders.

Volume reduction may therefore be beneficial in the short term, as suppliers compete to survive, but negative in the long term, with reduced investment and confidence. This is important as the Pathways Project predicted rapid cost reduction between 2014 and 2017 for those stories with high volumes, and only incremental improvement for the Slow Progression pathway. The sector will therefore need to achieve rapid cost reductions on the basis of reduced volumes.

Despite this risk, there appears to be relatively little which the sector can do to increase the volumes expected, with strict LCF limits in the UK and a low chance that volume projections across the EU will increase.

The sector therefore needs to achieve as much as possible with the volumes that are available, while taking additional actions to minimise the risk to those indicators most influenced by low volumes.

Certainty beyond 2020

Developers are facing a challenge to appropriately manage their development pipeline in the absence of clear guidance about the volume of offshore wind required beyond the end of the current LCF in March 2021. Within the context of increasing allocation risk arising through the CfD mechanism, developers must have a baseline level of certainty in the demand for their projects' capacity to balance the risk of failing to secure a CfD. This applies equally to the supply chain, which needs confidence in the post 2021 market to make the investments that are required to achieve the required cost savings.

Greater consideration of the balance between innovation and risk.

The drive to reduce costs across industry is manifested in a drive to innovate technology. However, this innovation could prevent a fall in the cost of capital, as investors view the unproven nature of new technology as an additional risk. Industry needs to continually balance the impact of innovation to drive efficiency and scalability, on financing costs. Investors have stated that they have greater appetite for proven components and processes, and would welcome greater standardisation where possible. In addition, developers should be aware of the total risk profile they present to investors; if a developer does not have a strong balance sheet, other risks should be minimised, for example through fewer contracts, an EPC wrap, best practice installation process or a technology (WTG/cabling/subsea stations) with greater operating experience.

De-risking the construction process

Construction risk remains problematic for the sector, with the sector continuing to show a high number of process failures. As a result, developers are finding it challenging to find an investment partner willing to assume construction risk, particularly when set against a backdrop of technology innovation. This presents a strong case for increased activity from institutional investors such as the Green Investment Bank (GIB) and the European Investment Bank (EIB), who are able to provide equity during construction, where developers might otherwise struggle to find investment at suitable cost.

For developers, investors suggest that further reductions in the number of packages can help reduce barriers and that greater knowledge sharing is required to demonstrate and embed scalability, reliability and best practice. Investors have greater appetite for proven components and processes, and would

welcome greater standardisation where possible, helping the balance between innovation and risk. In addition, developers should be aware of the total risk profile they present to investors; if a developer does not have a strong balance sheet, other risks should be minimised, for example through fewer contracts,

Construction risk also manifests through contingencies, with the sector showing no apparent progress in this area to date. The lack of progress on standard contracts further increases construction risk.

Potential equity pinch point

A further concern on the cost of equity indicator is the increased demand for equity in response to the large number of projects which are likely to seek financial close over the next two or three years. This is driven by projects seeking to meet RO closure deadlines, deliver under FIDeR and (once the winners are announced) the first CfD allocation round.

Impact of the introduction of CfDs

The move towards the new support regime in the UK will impact the sector in a number of ways. On the upside, the increased competitive pressure is likely to drive increased focus from developers on cost reduction, with the government now having what should be a clear price discovery mechanism.

However, the introduction of CfDs also introduces risks. The first is that it introduces strict limits on volume, discussed earlier, with significant rationing expected. The market is now clearly split into those projects which have access to financial support, and those that are competing for CfDs. Developers in this second group face significant uncertainty and acute allocation risk, which could impact progress against a number of indicators in this study.

For instance, the development risk premium is expected to fall behind target next year, pulling the cost of equity indicator behind target. This happens because if a developer has spent millions on one project, then this is likely to have to be recouped on another. Higher risk is reflected in a need for higher returns.

The design process may also be affected, with developers seeking to minimise development spend pre-contract award. This could reduce investment in site investigation and design optimisation, and reduce the willingness of the supply chain to engage, not knowing which project is likely to win. Developers have also had to modify designs to fit budget constraints which, with limited visibility, makes this challenging to do. Post award, developers need to meet strict deployment timescales therefore reducing the amount of design optimisation that could be completed. This may affect progress against the FEED and supply chain involvement indicator in future years.

The move to CfDs is likely to reduce the ability of developers to develop a pipeline of projects and in turn have the long term incentive to standardise the design of the offshore substation.

Delivering progress on specific indicators

In addition to progress on these broad themes, there is a need to deliver progress on the actions identified for specific indicators in Table 6-1. The OWPB should review and prioritise actions on the basis of both the significance and likelihood of a lack of progress.

7 RECOMMENDATIONS

On the basis of the analysis presented in this report, the following recommendations are made:

1. The OWPB should engage with equivalent bodies across Europe to share knowledge and improve the co-ordination of cost reduction initiatives across the wider industry.
2. The OWPB Supply Chain Group should consider what additional actions may be needed to ensure ongoing progress towards £100/MWh can be achieved, given reduced volume projections. This should, in particular, consider the long-term implications of reduced volume on jackets, purpose built installation vessels for (both) jacket and monopile installation, HVDC technology and standardisation of offshore substations.
3. Following the 2015 general election, the OWPB should work with DECC to provide greater clarity on the LCF budget available to fund CfDs in the post-2020 period.
4. The OWPB Finance Group should:
    a. closely monitor the potential risk of a capital shortfall, developing mitigation plans which consider the role of organisations such as the Green Investment Bank (GIB), the European Investment Bank (EIB) and Infrastructure UK (IUK) to increase their involvement in the sector.
    b. seek increased support for construction risk sharing from institutional investors such as the GIB and the EIB, who are able to provide equity during construction, where developers might otherwise struggle to find investment at suitable cost. This is particularly important in the project financing of megadeals (>£1bn)
    c. ensure greater consideration is given by the financial community of the balance between innovation and risk, with greater knowledge sharing to embed scalability, reliability and best practice in offshore construction.
5. The OWPB Contracting Group should:
    a. initiate action towards the development of standard contracts within 2015 to avoid this indicator being rated as 'missed target' next year.
    b. consider specific actions designed to reduce contingencies reserves.
6. OWPB Technology and Innovation Group should ensure:
    a. that following completion of the OWA project on Integrated Design that the principles are carried forward and implemented on a project.
    b. progress is made on wind farm wide control technology.
    c. demonstration sites are secured for Gravity Base Structures (GBS) and 66kV array cables.
    d. Actions are taken to secure investment in specialist jacket and monopile vessels. This should include a review of the potential risk of a vessel supply crunch in 2017, particular in deeper water.
7. The OWPB Grid Group should:
    a. Seek to progress standardisation of AC substations across the sector.
    b. Review the interaction between the OFTO regime and the ability for developers to use dynamic rating of cables and overplanting of generating assets.

APPENDIX A
Definition of Key Terms

The following definitions will be used in the CRMF:

Term	Definition
Target pathway	The cost reduction journey which the offshore wind industry should seek to follow from 2014-2020 in order to achieve £100/MWh. The pathway is described by a collection of indicators, which together set the benchmark against which progress is assessed.
Indicator	A component, item or process on which progress is needed for industry to be on track to deliver £100/MWh in 2020. Indicators are categorised as follows: • Level 1 indicator: The most fundamental, high-level indicator. • Level 2 indicator: A subdivision of a Level 1 indicator. • Level 3 indicator: A subdivision of a Level 2 indicator.[20] Note that wholly exogenous cost drivers such as commodity prices are excluded from the list of indicators.
Indicator vision	A statement of what needs to be achieved in 2020 such that industry is on track towards £100/MWh for that particular indicator.
Milestone	A statement of what needs to be achieved for a particular calendar year between 2012 and 2019 for industry to be on track towards £100/MWh for that particular indicator. The milestone acts as a benchmark for achievement.
Workstream	A collection of indicators grouped around a common theme (i.e. technology, supply chain and finance, as per the *Pathways Study*).
Milestone pathway	The collection of milestones which must be met year by year to achieve the 2020 indicator vision for a particular indicator.
Performance scorecard	An assessment of indicator progress towards its 2020 indicator vision. There are four possible outcomes: • **Ahead of target**: The indicator is on track to achieve the 2020 indicator vision in advance of the date envisaged. • **On target:** The indicator is on track to deliver the cost reductions required to meet its 2020 indicator vision. • **Behind target**: The indicator is behind on progress required to meet its 2020 indicator vision, but through targeted action the vision is still achievable. • **Missed target**: There is a high probability that the indicator will not achieve its 2020 indicator vision.

Table 7-1: Definition of key concepts

[20] Level 2 and level 3 indicators are introduced only when a greater granularity of detail is required to credibly assess Level 1 indicator status. For some cost reduction areas, level 2 and/or level 3 indicators are not currently required but may be required in future review cycles.

APPENDIX B
Methodological amendments

Through the implementation phase DNV GL have been considering ways to improve the scheme should the process be considered a success and be repeated in subsequent years. These innovations are divided into two main categories:

1. Innovations or cost reduction initiatives not captured in the list to date
2. Methodological changes to the approach.

Initial thoughts are as follows.

Potential innovations to be considered for inclusion in CRMF

In rough order of priority:

- **Vibro-piling of monopiles**. The OWA has undertaken work in this area completing an onshore trial in Germany. The Carbon Trust have stated that: '*The use of vibration piling has been predicted, and partly demonstrated in selected offshore applications, to decrease the piling time by more than half of that required for impact hammer driving*.'[21] At present this innovation is not considered in the framework
- **Economies of scale in projects.** A leading developer noted that there was good cost reduction potential through the development of larger projects which allow economies of scale to be achieved on a individual project level. This is not currently covered by the CRMF, with the Pathways Study assuming a fixed project size.
- **Delays pushing installation into the winter season.** A contractor noted that an improvement in the operational weather limit of 0.1m Hs is insignificant in terms of cost savings compared to project delays pushing installation into winter season. Although it would be challenging to assess, perhaps an indicator could be developed which seeks to track whether projects are delivering to schedule. For instance, West of Duddon Sands completed 2 months ahead of schedule.
- **Distributed transformers.** Henrik Steisdal (CTO) of Siemens presented a concept at the Carbon Trust innovation lecture whereby the offshore substation is no longer required, with step up transformers installed on the base of certain turbines which step up the power to the export cable. Although relatively little information appears to be available in the public domain this concept may be worth exploring further.
- **Wake effects.** Although considered within the FEED indicator, the study has had relatively little focus on the industry's understanding of wake effects. Added focus should be provided next year.
- **Grid charges.** A developer and an OEM noted that grid charges were a significant proportion of cost for projects, making it difficult to deliver an acceptable business case. Grid charges are largely outside of the industry's control but could perhaps be tracked as a key driver of cost.

[21] Jan Matthiesen, The Carbon Trust, quoted in Recharge on April 9th 2014. Article available: http://www.rechargenews.com/wind/offshore/article1357921.ece (accessed on 17/11/2014)

- **Marine Warranty Surveyors.** RenewableUK have flagged concerns with the ability and guidance used by Marine Warranty surveyors during the installation process. This may in due course lead to a industry standard or guideline.
- **Advanced welding techiques** work is ongoing through the Welding Institure on techniques to speed pile and MP production which could be considered.
- **Availability/data from SPARTA.** With the introduction of SPARTA it may now be possible to get access to data which was not available before. This should be explored.

Potential methodological changes to consider for next year

- **Timing of quantitative and qualitative scheme.** One developer noted that they had insufficient resource to participate in the scheme and suggested that the two schemes could be run consecutively as opposed to in parallel. This needs to be considered
- **Provide figure for this year and outlook for subsequent years.** At present the assessment reviews progress against the milestone for this year, with a discussion within the text as to how this indicator may evolve over subsequent years. This forward look could be formalised into an outlook rating and explicitly referenced for each indicator in the evidence log. For instance, indicator is 'ahead of target' for this year but outlook suggests likely to slip 'behind target' in 2016.
- **Greater engagement of the OWPB sub-groups.** Towards the end of the project PWC had a useful session with the OWPB finance group and associated financiers. This could be a useful model for other areas including installation and contracting.
- **Competition indicators.** Consideration should be given to whether a more nuanced definition of competition could be provided, with the number of suppliers active in the market not appearing to translate into how developers viewed compeitive pressures in the market. It may also be worth splitting competition at different indicator into different elements to reflect different water depths, voltage levels, etc. For instance, competition at 132kV and below and above.
- **Speak to the Carbon Trust.** The Carbon Trust are leading activity in various areas and are likely to have an interesting perspective on many of the indicators.
- **Removing DC arrays from the list of indicators** The evidence suggests this is not technically feasible by 2020 and so should be removed from the list for next year.
- **Blade lifting limits and design life milestones need to be amended as progress to date as exceeded 2020 expectations**
- **Sophisticated inventory management milestones need to be reviewed as it is not possible to quantify the proportion of projects using advanced methods.**
- **Approach to assessing operational weather limits.** More focus could be given to identifying and targeting the most weather limiting activities within areas such as monopile and cable installation. At present a general figure was given which may miss provide a more optimistic picture.

- **Asking stakeholders to submit input on an online survey sheet.** This would avoid time-consuming work copying and pasting submissions into the evidence log. The downside is that this could increase the actual or perceived hassle, providing a further barrier to stakeholder input.
- **Complete internal consultant literature review first** to allow more targeting of questions to stakeholders.

APPENDIX C
Evidence log

Issued as seperate document.

APPENDIX D
Indicator Tracking Tool

Issued as seperate document.

APPENDIX E
Final Design of the CRMF

Issued as seperate document.

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.