

Cost reduction monitoring framework 2016

Qualitative summary report

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Executive Summary

The results of the CRMF 2016 qualitative assessment are presented in Figure 1. The inner, middle and main rings represent the 2014, 2015 and 2016 level 1 indicator scores, respectively. The outer ring presents confidence in achieving the 2020 outlooks for each indicator, based on 2016 evidence.

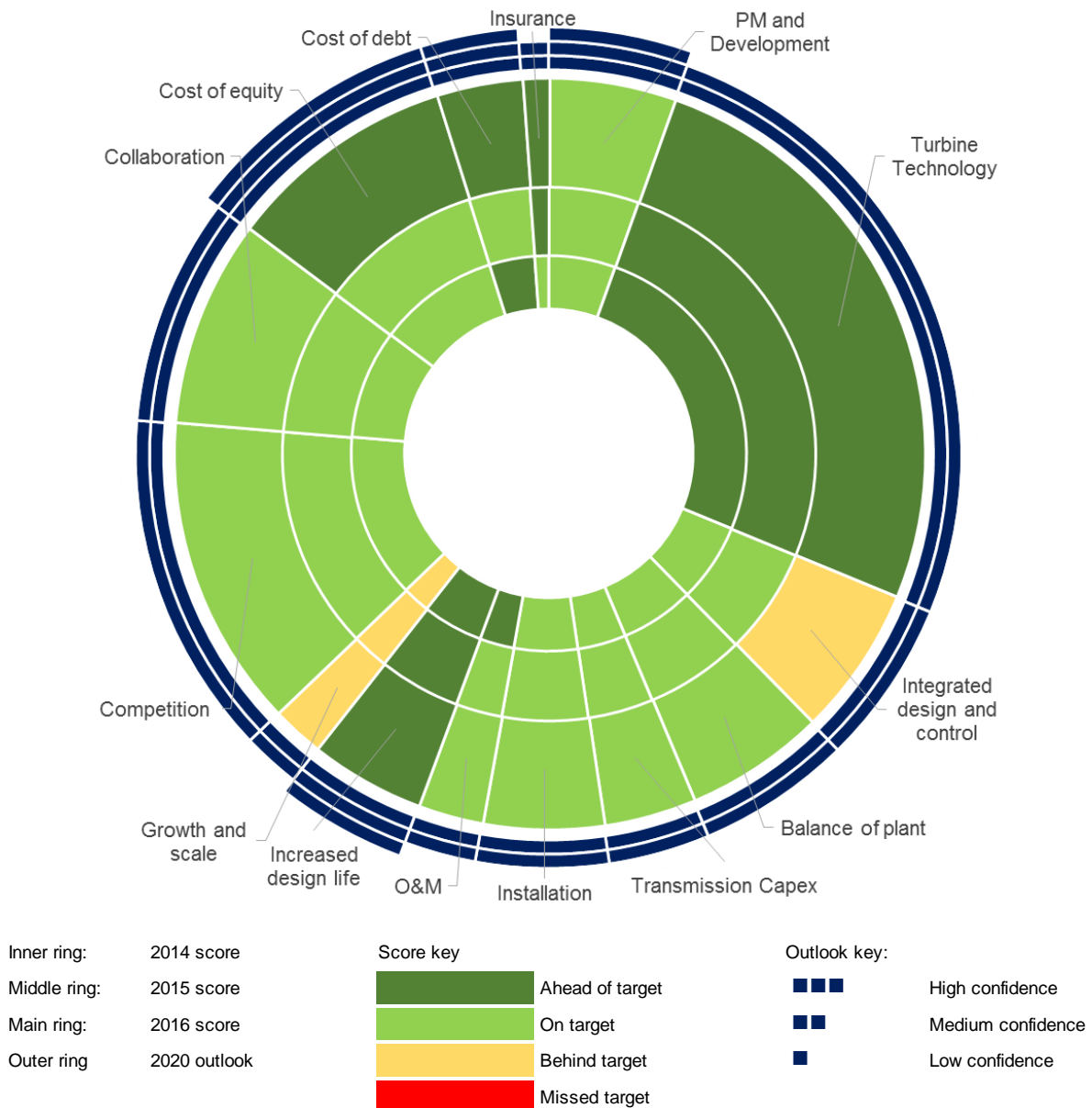


Figure 1 CRMF qualitative assessment results

The size of the slice is proportional to cost reduction weighting. Indicators which are now well ahead of target and have made a bigger impact on cost reduction than originally expected, such as cost of equity and cost of debt, could have justified having larger weightings in 2016. However, the indicator weightings have been fixed for consistency and ease of comparison with previous years.

Cost reduction 2014 - 2016

The offshore wind industry is on or ahead of target for the majority of the milestones that were set when CRMF was developed in 2014. As such, it is concluded that the overall target of £100/MWh for projects reaching FID in 2020 will be achieved ahead of target. Innovations with significant cost reduction potential continue to progress in the areas of technology, finance and the supply chain. The outer ring of figure 1 illustrates the outlook and shows confidence that cost reduction, as a result of these innovations, will be delivered.

It should be noted that progress in turbine rating, the cost of finance and competition in the industry has been faster and had a bigger impact on cost reduction than the CRMF originally anticipated. These should be revised in future cost reduction monitoring frameworks.

Growth and scale

Progress in the growth and scale of the industry remains behind CRMF targets. With over 2.5GW of additional UK capacity under construction in 2016 and a further 2.5GW in the pipeline, there is confidence that UK installed capacity will exceed 10GW by 2020. However the delay in the announcement of future auction rounds has led to uncertainty over future pipeline. Evidence showed an increasing focus on UK content in the supply chain but price and experience were cited as challenges for UK competitiveness in some areas.

Cost reduction through increased competition

The CfD process has increased competition between developers and in the supply chain. This has reduced supply chain margins and overall project costs as developers seek to submit accurate and successful auction bids. Innovation driven supply chain competition has supported competition at the developer level, and this combination has driven material change in the economics of offshore wind. A negative consequence of this has been the reduction in collaboration between developers and between supply chain competitors.

Cost reduction through reduced CAPEX

Turbine size and rating has progressed faster than anticipated by The Crown Estate (TCE) Cost Reduction Pathways (CRP) study¹, and had a significant impact on cost reduction. 6 – 8MW class turbines now dominate the market for new projects. Turbine innovations related to control and integrated design have not materialised as early as was expected.

Evidence has suggested the current oversupply of installation vessels, combined with the downturn in the oil and gas market, has led to reduced vessel rates and significant cost savings for construction projects.

Progress in balance of plant has been made in the last 12 months; notably in the production of jacket foundations, the first commitment of 66kV array cables to projects reaching FID, and an increase in the number of demonstration sites for new and innovative technologies.

Reduced cost of finance

The CRMF finance indicators (cost of debt, cost of equity, and insurance) are well ahead of target and have made a significant impact on cost reduction. There was almost universal recognition that the cost of finance has reduced, suggesting a more mature industry with lower perceived risk.

¹ <https://www.thecrownestate.co.uk/media/5493/ei-offshore-wind-cost-reduction-pathways-study.pdf>

Future challenges and risks

The competitive CfD process has driven cost reduction, but reduced the capacity for developers to work collaboratively on key issues and innovation challenges, which may have longer term cost implications.

Having made significant progress against the original CRMF targets, the industry should build on this momentum and develop a robust and deliverable cost reduction plan for post 2020.

Recommendations

Table 1 shows a list of recommendations for the OWPB to support further cost reduction in the years leading up to and after 2020.

Area	Recommendation(s)
Growth and scale	<ol style="list-style-type: none"> 1. Ensure further cost reduction beyond 2020 and maximise UK economic benefit through an agreed set of cost reduction priorities, timescales and monitoring process for collaborative actions across the sector. 2. Work with government to encourage and support investment in the UK supply chain. This should be built on a coordinated approach to industrial strategy, maximising the supply chain synergies between fabrication, assembly, port infrastructure, operations and maintenance and other sectors. 3. Identify and exploit opportunities to reduce development, consenting and deployment risk in the UK. Consider improved coordination of government policy implementation (energy and environment) and review successful policy and regulation from other European markets that could enhance the UK framework. 4. Continue to work with government via the Offshore Wind Industry Council (OWIC) on plans for further CfD auction rounds and longer term visibility of the market that would enable it to achieve its maximum potential.
Collaboration	Identify new mechanisms for developer collaboration which reflect an increasingly competitive market but ensure the benefits of industry knowledge sharing are continued without damaging competitive advantage.
Cost of insurance	Facilitate collaboration and knowledge sharing between the insurance community, industry and government to raise awareness on business interruption risk through transmission asset failures.
Turbines	Support projects which seek to both quantify the business case and clarify the market barriers for advanced control methods (e.g. nacelle mounted lidar based turbine control, and wind farm wide control). These technologies are available and offer cost reduction potential.

Balance of plant	Engage in consultation with foundation fabricators and installation companies to ensure that fabrication and installation cost reduction opportunities are understood, communicated and targeted at the design stage.
Project management and development	<ol style="list-style-type: none"> 1. Undertake a study evaluating the benefits of BIM (Building Information Modelling) enabled collaborative working environments for offshore wind project management and development. 2. Explore opportunities for reducing development, consenting and allocation risk.

Table 1 CRMF qualitative assessment recommendations

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1 Introduction

The Offshore Renewable Energy (ORE) Catapult, on behalf of the Offshore Wind Programme Board and the members of the Offshore Wind Industry Council (OWIC), delivered the Cost Reduction Monitoring Framework (CRMF) in 2014 and 2015. This report summarises the findings of the CRMF 2016 qualitative assessment.

The CRMF qualitative assessment is designed to track industry progress in Levelised Cost of Energy (LCOE) reduction leading up to 2020. This progress is tracked against indicators and milestones that measure development of innovations with potential to reduce costs in technology, the supply chain and finance.

The qualitative assessment is based on industry consultation focussed on the UK market but it incorporates evidence from activity worldwide, particularly in the rest of Europe. Following a description of the methodology, the findings from the consultation are presented and discussed. Based on the findings, the report concludes with a summary of challenges for the industry moving forward and recommendations for further cost reduction opportunities.

Appendix 1 provides detail on the results of the qualitative assessment. Appendix 2 provides a report titled: PN000163-FRT-004 CRMF 2016 Evidence Log, which includes anonymised records of the industry engagement and market intelligence used to assess progress against the CRMF annual milestones.

The results of the qualitative assessment are used to complement the findings of the CRMF quantitative assessment, which was delivered by KPMG and is summarised in the report (PN000163-FRT-001), provided in Appendix 3.

2 Methodology

The qualitative element of the CRMF is a bottom up, milestone-based framework which seeks to track progress against 70 level 3 indicators from 2011 to 2020. Each indicator is weighted according to its cost reduction potential (see Appendix 1). Based on evidence gathered from industry, ORE Catapult assess and score progress against annual milestones for each indicator. The weighted level 3 indicator scores are combined to calculate level 1 scores for areas of the technology, supply chain and finance work streams. The CRMF 2016 qualitative study was delivered in the following phases.

2.1 Design phase review

Based on experience and recommendations from the CRMF 2015 study, ORE Catapult initially undertook a design review and implemented a number of improvements, including:

- Addition of new level 3 indicators, annual milestones and cost reduction weightings for:
 - Turbine design - reflecting the cost reduction potential of turbine design considerations aimed at minimising OPEX (e.g. design for ease of maintenance).
 - Novel monopile design concepts - reflecting the cost reduction potential of monopile designs which reduce mass and/or installation times.
 - Increased capacity export cables - reflecting the cost reduction potential of higher capacity export cables.
 - Lightweight or novel offshore substations - now assessed as a separate indicator from Standardisation of AC substations.
- Addition of a level 3 indicator for UK Content in the supply chain (not a cost reduction indicator but related to UK economic growth).
- Consolidation of the two gravity based structures (GBS) level 3 indicators (Lifted GBS with turbine pre-installed and Floating GBS) into one indicator named, GBS Structures.
- Separation of the Turbine level 1 indicator into two new level 1 indicators named:
 - Turbine technology (includes level 3 indicators: Optimisation of rotor diameter, Blade design and manufacture, AC power take off, and Drive train concept)
 - Integrated design and control (includes level 3 indicators: Integrated design, turbine design, and turbine control)
- Incorporation of a simpler scoring system for assessing the 2020 outlook of each indicator. Participants were asked to rate confidence based on the system described in Table 2.

Score	Confidence in achieving 2020 target
1-2	Low confidence
2-3	Medium confidence
3-4	High confidence

Table 2 Definition of outlook scoring

2.2 Research and implementation

Following the design review, ORE Catapult gathered evidence from industry through:

- Desktop literature review;
- Consultation via an online questionnaire and/or interview;
- Internal review with ORE Catapult specialists;
- Market intelligence from public and non-public sources, including data from Renewable UK
- Review in workshops with OWPB working groups.

The collated evidence from all contributors is presented in the Evidence Log included in Appendix 2.

The ORE Catapult conducted a review of the evidence provided by industry, scoring progress in each indicator against the annual milestones. The confidence scores generated from the questionnaires were averaged at respondent level (e.g. developer etc) then all contributing sectors were averaged for each indicator. Where justified, adjustments were made to the scores by ORE Catapult for a small number of indicators, for example when evidence from interviews significantly contradicted scoring from the questionnaires. A detailed description of the annual milestones and outlook for each indicator can be found in the Evidence Log.

2.3 Consultation timescale

When reviewing the results of the qualitative assessment it is important to note that the consultation was carried out before the UK Government's announcement of the second auction round. However, the size of the auction is in line with previous announcements so is unlikely to have had an impact on the perception of growth and scale but will have helped to reduce uncertainty in the short term.

3 Results

The full results of the 70 level 3 indicator scores along with weightings and outlooks are presented in Appendix 1. The variance in the score compared to the CRMF 2015 qualitative assessment is also included to show how areas have developed in the last year.

Sections 4, 5 and 6 provide summarises the findings for the level 1 indicators (technology, supply chain and finance respectively). The level 1 indicators are weighted averages of the relevant level 3 indicators.

4 Technology work stream

This section presents the findings of the qualitative assessment for the technology indicators.

4.1 Project management and development

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	High confidence

4.1.1 Current status

Progress in project management and development as a whole remains ‘on target’. A noteworthy improvement was evidenced in site investigation between 2015 and 2016.

From being ‘behind target’ in 2015, the site investigation level 3 indicator is now ‘on target’. Supported by strong evidence, there is a general consensus in industry that the volume and quality of site investigations are increasing. This has been driven, in part, by the down turn in the oil and gas market which has reduced survey costs, incentivising developers to invest in more detailed survey work. Evidence this year showed a degree of variability in how and when developers interact with the supply chain. In some cases this has improved but there is still room for improvement in the timely sharing of site investigation data to optimise supplier designs.

There was evidence to suggest improvement in the degree of interaction between developers and the supply chain for Front End Engineering Design (FEED) pre-CfD application. Evidence collected highlighted a more collaborative approach to FEED in order to get the most accurate costs for CfD applications.

Progress in the use of floating lidar remains ‘ahead of target’ with further evidence of units being deployed in 2016 for wind resource assessment on demonstration and commercial projects. The adoption of floating lidar for bankable wind resource assessment has been faster than anticipated. As such, the industry is already experiencing significant cost savings from the use of floating lidar over met masts. One developer noted that they were able to carry out more detailed soil investigations due to cost savings from the use of floating lidar for wind resource assessment.

Increased interest in the application of structured collaborative working environments to offshore wind project development, such as Building Information Modelling (BIM), was shown. As such, progress in development phase project management remains ‘ahead of target’.

4.1.2 Outlook

There remains scope for improvement in project management and development to realise further cost reduction. The use of advanced wake modelling tools for array layout design is increasing (the work of the OWA has increased confidence in higher fidelity computational fluid dynamics wake models). However, the organisations consulted highlighted room for further development in multi-variable tools that take into account wakes, geotechnical and cable routing considerations simultaneously when designing array layouts.

A significant portion of the 2020 target has already been achieved for floating lidar. Evidence of ongoing trials (e.g. the OWA) to develop best practice will continue to improve confidence in the technology. In time it is expected that floating lidar will displace met masts for wind resource assessment realising significant cost savings for the industry.

Today there is a slow shift away from the use of ROVs (Remotely Operated Vehicles) towards the use of vessel mounted equipment and/or AUVs (Autonomous Underwater Vehicles) for surveying cable routes and landfall. Reducing the time spent offshore by vessels and vessel support technicians is an opportunity for cost reduction in site investigation; with further demonstration and validation, disruptive AUV technology could address this need.

Despite some evidence of improvement in 2016, the CfD process is likely to continue to limit the involvement of the supply chain for site investigation. As such, the level of pre-CfD site investigation and data sharing may continue to be sub optimal for UK projects, limiting the quality of supplier designs. This is in contrast to EU projects (e.g. in The Netherlands), where site investigation is tendered by Government as opposed to the developer. This approach reduces developer risk and can improve the quality and volume of data available to suppliers in the development phase. This difference in policy is a contributing factor to lower successful bids in the Netherlands and Denmark auctions compared to those in the UK.

4.2 Turbine technology

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target	No change	Medium confidence

4.2.1 Current status

Progress in turbine technology is assessed as ‘ahead of target’. The trajectory of turbine rating has been far beyond that originally envisaged by TCE CRP; 6MW+ turbines now dominate the market for new UK and EU projects. Larger turbines present challenges for blade technology that are being addressed through innovations in design, materials, coatings and test methods.

As in previous years, turbine rating remains ‘ahead of target’. The majority of EU projects that reached FID in 2016 have committed to using turbines in the 6 to 8MW range, as shown in Figure 2. In the UK, 2016 saw the first commercial deployment of the MHI Vestas V164 8MW platform at the 258MW Burbo Bank Extension project. Siemens Wind Power, who have already installed 6MW turbines, will supply 7MW turbines for the Beatrice and Walney Extension East

projects. MHI Vestas have announced they will increase the output of their V164 platform to 8.3MW on the upcoming EDF Blyth Offshore project, whilst Siemens unveiled its new SWT-154 8MW turbine in July, the first of which will be installed in early 2017.

The turbine drivetrain concepts indicator has come down from ‘ahead of target’ in 2015 to ‘on target’ in 2016. Whilst there remains a good mix of proven mid-speed and direct drive turbines in the market, there is little evidence to suggest that testing of variable speed drivetrains and superconducting generators is underway. The main driver for cost reduction through drivetrain design is to reduce CAPEX. Secondary drivers are uncertain; whether the focus is on improving drive train configurability to maximise efficiency, or on optimising design for reliability. The emergence and widespread use of direct drive turbines combined with minimal progress in superconducting generators suggests the latter.

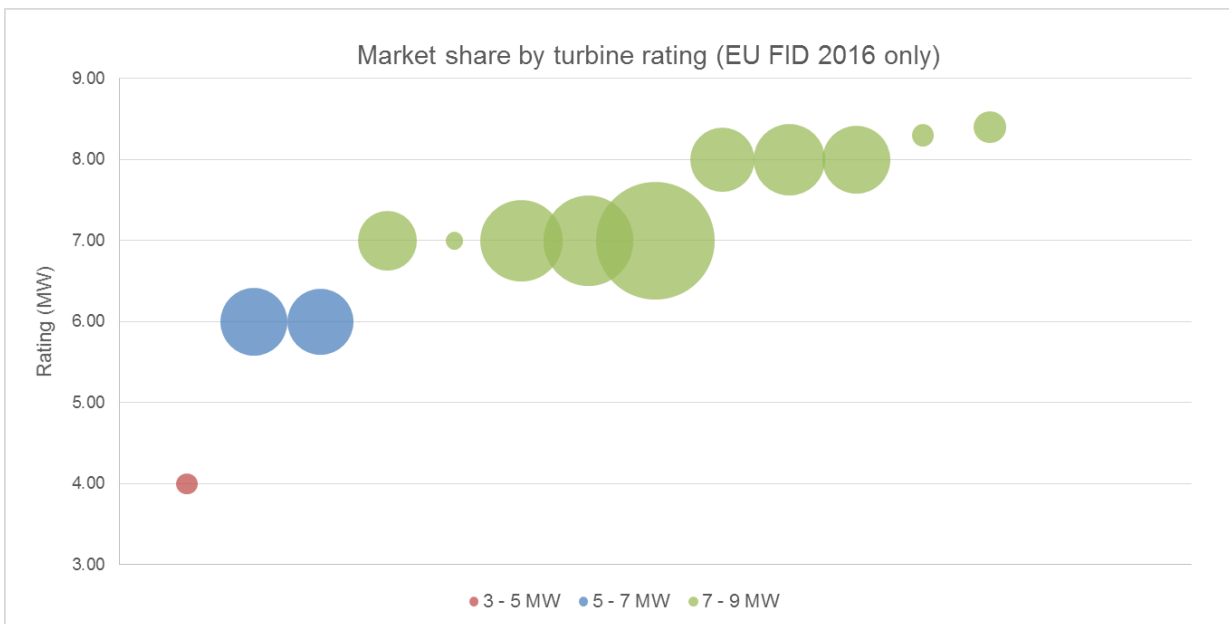


Figure 2 Market share by turbine rating (EU FID 2016 only)

Progress in rotor optimisation (i.e. optimisation of ratio between rotor diameter and rated generator capacity) has fallen to ‘behind target’ this year. Evidence provided for this indicator did not reveal any plans for turbine OEMs to release increased rotor diameters for the current class of 6-8MW turbines. The benefit being the potential to optimise AEP for a given generator capacity through an upgraded turbine product with longer blades. The trend to steadily increase rotor diameter on existing turbine products of fixed capacity has been evidenced in the past generation of turbine class (2-4MW). Challenges in the design and testing of XL blades (80-90m) may mean the industry is taking a more conservative approach to the release of larger rotor diameter turbines, and hence the potential for significant LCOE reduction remains.

Blade design and manufacture is now ‘ahead of target’ with a good sample of evidence that suggests blade design to optimise performance and reliability is improving. The issue of blade leading edge erosion remains a concern for the industry, in terms of costs associated with maintenance and lost energy production. The unveiling of new leading edge protection solutions (production and retrofit) from Siemens and LM provides hope that the issue and cost impacts can be mitigated. Progress was noted in the development of novel test methods that seek to more accurately represent the structural loads on large blades during accelerated life testing.

4.2.2 Outlook

The outlook for turbine technology as a driver for cost reduction remains positive.

The 2020 vision for turbine rating describes a market where 40% of projects contract 7-9MW class turbines and the first 9MW+ turbines become available. The first half of this vision looks more than likely to be achieved as 6MW+ turbines now dominate the market for projects reaching FID with the majority in the 7-8MW class. Turbine OEMs are engaged in R&D working on 9MW+ designs, however significant investment by OEMs will be required to bring 9MW+ products to market before 2020. Without some confidence that there will be a sufficient market to sell these products, at least one OEM suggested that a new platform with a higher rating is unlikely until the situation changes.

Release of upgraded 6-8MW products with optimised rotor diameters before 2020 will be dependent on whether blades of 80-90m in length can be tested, certified and manufactured in time to keep up with progress in turbine rating. Based on the calculation method developed for TCE CRP, the Adwen AD 8-180 (8MW rating with 180 m rotor diameter) is a design with an optimum rotor size for its generating capacity and certification is expected in 2017.

With respect to blade design and manufacture the industry outlook is positive. More than one OEM is intending to investigate modular or novel blade designs in the coming years. With the recognition that leading edge erosion is an industry issue, there have been advancements in the application of new protective coatings at the blade production stage. These steps should hopefully mitigate the problem and cost impacts. However, with much research still to be done to understand the physics of erosion failure and improve the test methods, it remains to be seen how these solutions will perform in the field.

4.3 Integrated design and control

2015 finding	2016 finding	Variance	Outlook
On target	Behind target	Down	Medium confidence

4.3.1 Current status

This level 1 indicator is new for the CRMF in 2016 and incorporates existing level 3 indicators on integrated design (of turbine and substructure) and turbine control, and a new level 3 indicator on turbine design (for ease of maintenance).

Evidence last year showed incremental improvements in individual turbine control algorithms were being introduced by OEMs, however progress in sophisticated control using nacelle mounted lidar inputs was less advanced. This year there was no evidence to suggest the situation has changed causing turbine control to fall 'behind target'. Turbine OEMs have shown interest in nacelle mounted lidar for power curve verification but not for turbine control. Wind farm level control continues to gain academic traction with some OEMs and developers stating interest in future demonstrations projects. The cost benefits of this approach are not anticipated until post 2020.

Evidence from both OEMs and developers suggested that turbine design has generally evolved to account for maintenance activity and safety considerations during the operations phase. For example, the design of nacelle layouts to make offshore maintenance faster, easier and safer,

supporting reductions in OPEX whilst at the same time focussing on manufacturability and CAPEX.

Integrated design is now assessed as a ‘missed target’ as no projects have reached FID in 2016 with an integrated design of the turbine and support structure. Iterative sharing of load data between turbine OEMs and the lower supply chain to improve foundation design was evidenced, however, due to commercial constraints no project has taken the step to fully integrate the design of both components.

4.3.2 Outlook

The outlook for turbine control is uncertain. It is unlikely, given the slow pace of deployments on commercial projects, that nacelle mounted lidar will be used for anything other than power curve verification before 2020. Lidar increases CAPEX, therefore the cost benefits of lidar based control may need to be addressed before it is integrated into turbine designs. Wind farm wide control has shown promise in R&D projects driven by the academic community, but again based on this year’s evidence it is unlikely it will be deployed at commercial scale before 2020.

The outlook for a commercial project contracting a fully integrated design before 2020 is not optimistic. Many of the organisations consulted stated that this must be driven by the OEMs. Progress to date has not been sufficient to achieve the 2020 target of universal integrated design. The recent press release² announcing Siemens plans to provide both 7MW turbines and novel gravity jacket foundations for the 28MW Nissum Bregning Vind pilot project, off the coast of northern Denmark, suggests future promise for this indicator beyond 2020.

4.4 Balance of plant

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	Medium confidence

4.4.1 Current status

Progress in balance of plant remains ‘on target’. Particular highlights for 2016 include the first addition of 66kV array cable designs in projects reaching FID and the increased production of jacket foundations.

In 2016 cable system providers JDR and Prysmian Group both unveiled their fully verified 66kV array cable solutions. Evidence has shown that 66kV technology will be used on a UK demonstration project in 2017 and has also been committed to commercial UK and European projects that have reached FID in 2016. Last year the 66kV indicator was ‘behind target’ because no projects had reached FID with this technology. The significant progress this year in technology qualification and commitment to projects has raised this indicator to ‘on target’.

The indicator for Extra-large (XL) monopiles and improved design standards has come down to ‘on target’. Last year the indicator was ‘ahead of target’ as there was evidence to show that large diameter monopile designs had been manufactured and installed in 2015. This year evidence has again showed progress with 8m piles being manufactured and installed using novel piling noise mitigation technologies such as vibropiling, shrouds and bubble curtains.

² <http://www.windpoweroffshore.com/article/1409441/new-siemens-foundations-confirmed-danish-pilot>

Design guidance emerging from the Structural Lifecycle Industry Collaboration (SLIC) and Pile Soil Analysis (PISA) joint industry projects is also being considered in new monopile foundation designs. Evidence from engagement suggested 10m diameter piles exceeding 1300t in weight could be manufactured, however constraints around noise mitigation and installation technologies, which have yet to be properly tested at this scale, mean this indicator could not be assessed as 'ahead of target'.

Novel monopile concepts was a new indicator introduced to the CRMF in 2016. To be 'on target' the indicator requires at least one project to have demonstrated a radically different monopile foundation design (e.g. no transition piece). This was successfully achieved in 2016 with a July press release³ stating that monopiles were being installed at the Eneco Luchterduinen offshore wind farm without a transition piece. By removing the transition piece, the potential cost reduction is through the reduction in the use of steel and the installation time saving. The exact cost saving has still to be determined, preventing this indicator from being assessed as 'ahead of target'. There is also no evidence to suggest that UK projects are likely to adopt this approach in the near future.

Suction bucket, a novel foundation concept that can be applied to both jackets and monopiles, is assessed separately. Last year this indicator was 'on target' as demonstration projects using suction buckets for jacket and met mast foundations were conducted on European projects. This year the indicator remains 'on target' with the announcement⁴ that the Hornsea One project will deploy suction bucket jackets for around one third of the foundations.

Since 2015, the progression in the production of jacket foundations and commitment of the technology to projects reaching FID in 2016 has moved jacket design and manufacture from 'behind target' to 'on target'. Near term deep water (40-55m) projects using jackets include Beatrice, Wikinger, East Anglia One and Hornsea Project One. There is now suitable demand to occupy capable EU manufacturing facilities. However, one foundation supplier did note that jacket manufacturing from a supply chain perspective remains challenging. A peak in demand is expected for 2017/18, however beyond this the outlook is uncertain and there are insufficient incentives to invest in facilities.

Progress in GBS structures is 'behind target'. There have been no successful trials or demonstrations of GBS being used for a turbine in 2016. The Blyth Offshore Demonstration project is currently fabricating 'float out and submerge' GBS foundations for five MHI Vestas 8MW turbines, however these will not be installed in 2016, preventing the indicator from being 'on target'.

4.4.2 Outlook

The outlook for XL monopiles is generally positive. The envelope of monopile design continues to evolve to accommodate larger turbines in deeper waters. Outputs from the PISA and SLIC joint industry projects are now being incorporated into future designs. Mass and piling noise may constrain installation of 10-12m diameter monopiles in future. Most consultees believed noise limits will reduce over time. Trials of technology innovations for noise mitigation, such as vibro-piling, are underway which may provide a solution for XXL monopile installation.

Compared to 2015, the industry is more optimistic about achieving the 2020 vision for jacket design and manufacturing. An increase in the use of jackets has ensured, for the near future, a pipeline of projects for purpose built jacket manufacturing facilities. The clear message from consultation was that standardisation of design and manufacturing is the key to cost reduction in

³ <http://winddays.com/innovations-in-luchterduinen/>

⁴ <http://www.rechargenews.com/wind/867878/dong-to-deploy-suction-bucket-jacket-foundations-at-12gw-hornsea-1>

jackets. The variance in jacket designs (often optimised for each project) is currently a challenge for fabricators. This could be countered through partial standardisation of design in jackets, which would ease logistics and improve economies of scale for manufacturing. Evidence provided suggested this is ongoing and will be achievable in future years.

With first movers on 66kV cables this year, the industry has increased optimism for the technologies utilisation pre-2020. Lack of suitably skilled labour for installation and commissioning remains a potential barrier, but this is now expected to reduce in coming years. As the market matures it is expected further cost reduction will be achievable through increased competition and economies of scale in 66kV cable supply.

4.5 Transmission asset CAPEX

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	Medium confidence

4.5.1 Current status

Transmission asset CAPEX remains ‘on target’. Both standardised and distributed substation architectures are offering the potential for significant CAPEX savings. HVDC grid systems will not be utilised on UK projects before 2020.

The CRMF 2016 has two indicators related to substation design – ‘Standardisation of offshore AC substation’ and ‘Lightweight or novel substations’. Progress in both indicators was assessed as ‘on target’. Evidence did however highlight a range of divergent approaches to substation design for new projects.

In the near future, substations with standardised designs, or standardised elements of design, will be deployed on UK and EU projects by DONG and TenneT. With a large pipeline of projects there can be economies of scale in having standardised substation designs. However, some developers preferred a degree of flexibility in design to accommodate differences in project specific factors (e.g. site capacity and distance from shore). In these instances, the novel and lightweight Siemens OTM (offshore transmission module) concept has gained traction in the market. The Beatrice project will deploy the first Siemens OTM and will use two lightweight substation topsides on a foundation design shared with the wind turbine support structures.

Booster stations (additional platform midway to shore) was assessed as ‘ahead of target’. Last year the indicator was ‘on target’ with a number of projects considering the technology in FEED. This year DONG have announced⁵ it will use the world first reactive compensation station (RCS) for the Hornsea Project One, with the contract for construction awarded to Babcock in Rosyth.

Compact HVDC systems was marked as a ‘missed target’. Due to the challenges and high initial costs (as evidenced on German projects that have used HVDC systems) developers are reluctant to consider this concept for other than far offshore sites. The tight timescales for projects with a CfD to commit to commissioning dates is another dissuading factor for HVDC. As a result it is unlikely the technology will be used on projects reaching FID in the UK before 2020.

⁵ <http://www.dongenergy.co.uk/news/press-releases/articles/dong-energy-awards-multi-million-pound-contract-to-babcock-for-world%E2%80%99s-largest-offshore-wind-farm>

4.5.2 Outlook

The split in opinion on standard versus flexible substation design reflects the low confidence outlook for Standardisation of AC platforms. Some developer’s feel that adopting a standard design today may restrict opportunities for future cost reduction through the evolution of substation technology. It is therefore unlikely that by 2020 all projects will have substations designed with standard rating and voltage, with substantial standardisation of other features.

Novel and lightweight offshore transmission architectures (e.g. Siemens OTM) are likely to increase in use. Further collaboration between turbine and transmission asset OEMs could advance the uptake of this technology as it is currently only available to customers of one OEM. A large opportunity for cost reduction with this technology is to locate the transmission platform on the same foundation as a turbine and this remains a significant technical challenge.

The use of overplanting and dynamic rating of cables is an area of future promise for developers seeking to maximise the output of transmission assets, which has been demonstrated on low cost projects announced in the EU. As such is expected to increase in future.

4.6 Installation

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	Medium confidence

4.6.1 Current status

Progress in installation is still ‘on target’, however there is significant variation in the progress of the level 3 indicators.

As in 2015, progress in lifting conditions for blades is assessed as ‘ahead of target’. Evidence has shown that the 12 m/s 2020 target has already been comfortably achieved, which includes blades for 6-8MW turbines.

In 2015 utilisation of feeder vessels (for turbine installation) was ‘behind target’ as despite evidence of consideration in FEED their use was not evident. Based on 2016 evidence this indicator is now marked as ‘missed target’ as it is unlikely feeder vessels will be utilised on projects before 2020. Due to a number of factors feeder vessels are now regarded by many developers as unnecessary. The most dominant factor is the present day reduction in vessel rates, which reduces the economic justification for a fast feeder vessel solution.

Operational weather windows for monopile installation continues to be ‘ahead of target’ with engagement this year suggesting that 2.0m Hs has been achieved, surpassing the 1.9m Hs target for 2016. In contrast, progress in purpose built monopile installation vessels remains a ‘missed target’. Figure 3 shows that with the exception of Scylla in 2015, there has been low investment into vessels capable of installing the largest (>1000t) monopiles in recent years. There are no new purpose built floating DP vessels for monopile installation on the market and no evidence suggesting investment in such vessels is likely. Reduced activity in the oil and gas market has generally reduced the day rates for offshore construction vessels. Evidence has suggested this factor, combined with a low future pipeline has discouraged investment into purpose built monopile installation vessels.

Progress in purpose built jacket installation vessels is now marked as a ‘missed target’. In 2015 this indicator was ‘behind target’ with no floating DP vessels available and very few vessels with capacity to carry greater than 3 jackets simultaneously and/or operate in 40m+ water depths. This year the situation has not changed considerably. Slow uptake of jackets and reduced day rates of current offshore construction vessels has reduced demand and dissuaded investment into purpose built jacket installation vessels.

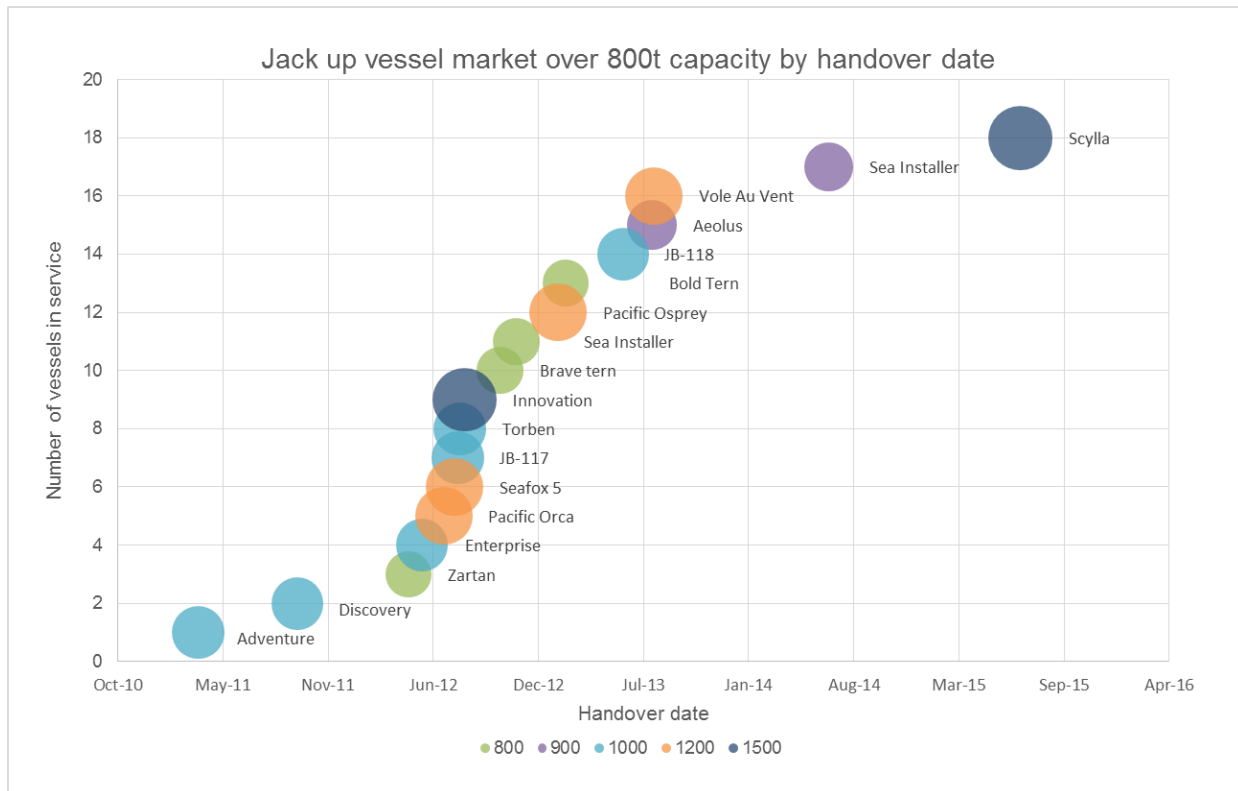


Figure 3 Jack up vessel market over 800t capacity by handover date

Flexible sea fastenings have not progressed since last year and is now assessed as a ‘missed target’. There was no evidence of this technology used for jacket installations, however sea fastenings are often recycled on wind turbine installation vessels (WTIV). Compared to a tower or nacelle, jackets are more complex and bespoke structures. Standardisation of jacket designs may help to unlock the cost reduction potential of flexible sea fastenings, which from evidence the industry still recognise as valid.

As in 2015, progress in cable installation processes is ‘ahead of target’ for this year. Both the supply chain and developers consulted provided evidence to suggest cable installation processes and technology developments are markedly improved over those in use 3-5 years ago. Cable vessels and tooling was ‘on target’ with clear evidence of installation projects employing specialised vessels with innovative installation tools.

Through greater experience and the introduction of improved technology, processes and cable installation vessels, weather limits continue to increase for cable installations. The indicator is marked as ‘ahead of target’ in 2016, up from ‘on target’ in 2015. Evidence provided suggested cable installations taking place in sea conditions well beyond 1.6m Hs.

4.6.2 Outlook

In future it is possible that operational weather limits for blade installations will increase beyond the 2020 vision of 12 m/s, which has already been achieved. However, the drive to do so may reduce with technology investments to increase the limits following a law of diminishing returns.

Considering the current oversupply of offshore construction vessels with reduced rates, it is unlikely feeder vessel concepts will be used on projects before 2020.

For the current and near future market volume, there exists sufficient capacity in the supply of suitable vessels to install monopile foundations. A period of ‘business as usual’ is expected with investment into specialised vessels and new installation methods unlikely in the medium term. Improvements in monopile installation vessels is a ‘missed target’. However, cost reduction in monopile installation is taking place through increased competition and capabilities of the current vessel fleet. The lack of investment in new vessels is however casting doubt over the industries capacity to perform monopile installation in 2.5m Hs by 2020.

For projects installing jackets, there was no evidence suggesting possibilities of delays through lack of availability of suitable vessels. Evidence did raise concern over the capabilities of existing jack up vessels to install jackets in deep waters. If these concerns materialise there could be a drive to develop specialised vessels and/or an increase in the use of floating/barge/shear-leg type vessels for deep water projects.

The future outlook for cable installation is positive with the expectation that the 2020 vision for weather limits (3m Hs) is achievable. This confidence is largely driven by the progress in cable installation vessels and tooling that is meeting the specific needs of the offshore wind sector.

4.7 O&M

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	Medium confidence

4.7.1 Current status

General progress in O&M as a mechanism for cost reduction is assessed as ‘on target’.

Turbine condition based maintenance (CBM) was assessed as ‘ahead of target’ in 2015 with the 20% threshold thought to have been achieved for projects reaching FID that demonstrated a condition based approach to turbine maintenance. For projects reaching FID in 2016 there was little evidence to suggest a noticeable increase in the use of CBM. Evidence showed that due to commercial constraints and warranty implications, conservatism still dominates and approaches to maintenance are unlikely to be based on condition monitoring alone. As a result this indicator is assessed as ‘on target’.

Progress in access from vessels to turbines is assessed as ‘on target’. In 2015, a sea state of 1.5m Hs was widely recognised as the de-facto industry standard for turbine access. This year evidence showed that innovative vessel and access technologies (e.g. walk to work, SWATH CTV, SOV) can exceed 1.7m Hs access limits. However, based on evidence, the marginal increase in working limits is not yet a strong justification for the additional investment in these systems. Forecasting crew accessibility is still largely dependent on commercial weather forecasts. Evidence showed there is room for improvement through the integration of weather,

local site bathymetry, vessel motion, and transit and accessibility data. The level of experience of vessel skipper and crew has a significant impact on access decisions.

Marked as ‘on target’ in 2015, progress in inventory management is now assessed as ‘behind target’. Last year, evidence showed use of advanced data driven methods but this did not improve further for projects reaching FID in 2016. Evidence of information sharing between OEMs and asset owners to support advanced inventory management was also minimal.

Progress in offshore crew accommodation is assessed as ‘on target’. There have been several announcements in 2016 of projects utilising variants of this concept to support offshore logistics (mainly focussed on the use of SOVs). Plans for the use of floating offshore accommodation have been announced and one EU project is currently using a fixed offshore crew accommodation platform.

Transmission asset O&M has progressed from ‘behind target’ in 2015 to ‘on target’ for projects reaching FID in 2016. Evidence this year showed some improvement in the application of condition monitoring of transmission assets. However, progress is slow and not universal as condition-based maintenance strategies for OFTO assets are not currently incentivised.

4.7.2 Outlook

The outlook for O&M is positive, but still noting some conservatism in the future use of state of the art technologies, such as advanced condition monitoring and specialised vessels.

Turbine condition monitoring is expected to continue to increase over time as the benefits of data driven approaches to maintenance become more evident for offshore wind farms. Much of the technology exists, yet future innovation is required in contracting and analytical techniques for data to ensure the benefits of CMS are maximised.

The 2020 outlook for turbine access is uncertain where a number of different scenarios can be foreseen. This requires transfers from vessel to turbine to take place in 2.5m Hs for 90% of projects. Third generation CTVs and SOVs with ‘walk to work’ systems are available and are capable of providing access in these conditions. The business case for these systems and/or offshore crew accommodation is still evolving for ‘near shore’ projects. Evidence suggested that the economic ‘pinch point’ for these innovations is expected for projects in development approximately 70km from shore where travel/commuting time combined with sea state limits makes more expensive technology attractive.

The current scheme in the UK does not incentivise design improvements in OFTO assets which optimise O&M and availability. Until this is fundamentally changed, the 2020 targets for cost reduction through this indicator are unlikely to achieve full potential.

4.8 Design life

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target	No change	High confidence

4.8.1 Current status

Progress in design life of offshore wind farms is 'ahead of target'. Each developer consulted noted a design life of 25 years or more for projects in design or under construction.

4.8.2 Outlook

Based on evidence this year the 2020 vision for design life has already been achieved. The potential to extend asset life beyond 25 years is still considered an opportunity for cost reduction. Asset life fatigue in the marine environment, particularly on foundations, was evidenced as a barrier to design life improvement and/or asset life extension. Innovation in structural health monitoring and analytical techniques are necessary to further reduce conservatism and advance asset life beyond 25 years.

5 Supply chain work stream

This section presents the findings of the qualitative assessment for the supply chain indicators.

5.1 Growth and scale

2015 finding	2016 finding	Variance	Outlook
Behind target	Behind target	No change	Medium confidence

5.1.1 Current status

Growth and scale remains ‘behind target’, with slow progression rates for installed capacity in both the UK and EU markets.

To be ‘on target’ in 2016 the indicator for UK growth and scale requires 6GW of fully commissioned capacity. As of October, an installed base of 5.098GW was fully commissioned⁶. According to the CRMF annual milestone, this is ‘behind target’. However construction has taken place on a number of projects (Burbo Bank Extension, Dudgeon, Galloper, Race Bank, Rampion, and Walney Extension), therefore over 2.5GW of installed capacity will be commissioned in 2017/18. Construction for East Anglia One, Beatrice, Blyth Offshore Demonstration Project and Hornsea One will also begin in 2017/18, with combined capacity for a further 2.5GW. The progression rate for installed capacity has been slow in 2016, but is in line with construction targets and will significantly pick up in the remaining years pre-2020.

The announcement by the UK Government that the next CfD auction round will take place in the first half of 2017 has been welcomed. In addition there was an announcement that the levy control framework (LCF) will be extended to 2026. However, there was no firm detail on when future auction rounds will take place and the level of budget expected to be made available. Evidence highlighted this uncertainty as a hindrance to investment in the supply chain.

UK content was a new indicator introduced to the CRMF this year. Whilst this is not a cost reduction indicator, it has an impact on UK economic growth. The majority of respondents working on UK projects reported a policy for targeting UK content in the supply chain, driven by Government desire to demonstrate impact. The biggest opportunities for UK content were reported as O&M, manufacturing of blades and foundations, and electrical system assets. Some participants felt that UK content was more expensive, however many recognised the need to find the right balance between UK content and project cost.

Progress in growth of the EU (including UK) market was assessed as ‘behind target’. As of October 2016, fully commissioned capacity in the EU stood at 10.996GW⁶, which is short of the 12GW targeted by the milestones for this indicator. There is however an expectation that the CRMF target of 25GW installed EU capacity by 2020 will be met.

5.1.2 Outlook

With forecasted construction rates, the UK and EU markets look set to achieve the CRMF 2020 targets of 10GW and 25GW installed capacity, respectively. However, there is still uncertainty

⁶ Renewable UK Offshore Wind Project Intelligence 2016

over the level of revenue support that will be available for new UK projects both before and beyond 2020; this reflects the medium confidence in the growth and scale indicators. The timing of, and level of support that will be available in the third and fourth auction rounds is unknown. Some clarity on this could help to maintain the current momentum of the sector and increase confidence.

5.2 Competition

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	Medium confidence

5.2.1 Current status

General progress in competition is assessed as ‘on target’. Notable changes occurred in the level 3 indicators for competition in turbines (down from last year) and HV cables (up from last year). Whilst not tracked by the CRMF milestones, reduction of supply chain margins, driven by the competitive CfD scheme, was reported by many as having a significant contribution to cost reduction.

Turbines

Due to consolidation in the market, progress in turbine competition has fallen to ‘behind target’ as only three OEMs are now considered to have proven offshore products. In last year’s study Siemens, MHI Vestas, Senvion and Adwen were considered OEMs with available products and an offshore track record. This year, consolidation of Siemens and Gamesa has effectively removed Adwen from that list.

Senvion have announced an order for a project in Germany and GE are expected to supply turbines to French projects around the end of the decade. However, supply of 6-8MW class turbines for UK projects reaching FID in 2016 was only from Siemens and MHI Vestas. There was limited evidence of projects selecting alternative turbine suppliers and competition was therefore considered low and unlikely to increase.

Support structures

Progress in competition in support structures is assessed as ‘on target’ with a positive evaluation of competition in supply of monopiles and jackets by those consulted. There are limited examples of projects using low-cost (non-European) suppliers which prevented this indicator from being assessed as ‘ahead of target’.

Electrical

Based on industry feedback, progress in competition in HV topside equipment supply is assessed as ‘on target’. Despite the merger of NKT and ABB, there remain at least 4 suppliers of electrical systems for HV topsides and at least as many fabricators delivering HV topsides. Progress in HV cable supply has moved up to ‘ahead of target’ this year, with a noticeable increase in competition in 66kV cable supply (3 to 4 suppliers considered capable of supply).

Installation

The 2020 milestone for competition in WTIV supply describes a mature EU market with a variety of contractors capable of supplying 15-20 vessels for installation of 6MW+ turbines. Evidence this year suggests this indicator is 'ahead of target', with around 15 proven WTIV active in the market, including more than 4 capable of lifting 6-8MW class turbines. Suitable competition in supply of WTIV was evidenced, driven in part by the low pipeline of future projects causing a slight oversupply. The oil and gas downturn has stimulated further competition in WTIV supply with compressed day rates.

Competition in supply of foundation installation vessels remains 'on target'. Evidence last year suggested healthy competition in the supply of WTIV with crane capacity to install foundations in the region of 800t, but limited competition in the supply of HLV with crane capacity for next generation monopiles (over 1000t). The situation this year remains relatively unchanged, but evidence did suggest poor competition in vessels with capacity to install jacket foundations in deep (40m+) waters, and low suction bucket experience.

Competition in supply of vessels for installation of both export and array cables is assessed as 'ahead of target'. As in 2015 there is sufficient evidence to suggest the 2020 milestone for this indicator has already been comfortably met. There is a fleet of at least 20 vessels or barges with suitable experience, and more than one operator launching new purpose built vessels. This is considered a slight oversupply for the current market volume which has enhanced competition.

5.2.2 Outlook

Turbines

Consultation determined that for projects up to 2020, competition in turbine supply is likely to be sufficient and will be dominated by two OEMs. A 'medium confidence' was expressed by industry in the future outlook for this indicator, reflecting the feeling that the level of competition was unlikely to increase with expectation of further consolidation amongst turbine OEMs.

Support structures

The number of projects committed to using jacket turbine foundations is likely to increase in future placing downward pressure on demand that may tend towards under supply. This, coupled with the trend for developers to split jacket fabrication across a number of suppliers to reduce risk, could see more jacket foundation contracts placed outside of the EU in future years.

Competition in suppliers of ~10m diameter monopiles weighing over 1000t is perceived to be low, which could have an adverse effect on future supply if projects continue to push the application envelope of monopiles (i.e. for large turbines in 40m+ water depths waters).

Electrical

Competition in HV topside equipment supply may be enhanced in future through non-EU HV topside suppliers entering the market, which remains a possibility. Competition in cable supply is not expected to change in the years leading up to 2020. Potential supply chain issues are foreseen with increasing demand for higher voltage export cables, with evidence of limited competition in this area.

Installation

For the current class of 6-8MW turbines there is sufficient competition in the supply of capable WTIV, as evidenced by industry. Future development of 9-10MW turbines and/or projects in

significantly deeper waters may increase demand for specialised WTIV where the capabilities and capacity does not presently exist, however this is not expected to happen pre 2020.

Similarly for foundation installation there is high confidence that the current fleet of vessels is sufficient to meet the current pipeline of projects up to 2020. Competition in HLV or WTIV capable of installing <1000t foundations was evidenced as strong. Above 1000t the availability of vessels with suitable lifting capacities reduces, similarly for operations in significantly deeper waters. Evidence noted that a lack of market certainty is discouraging investment into HLV with greater lifting capacities and working depths; this may pose a risk to the industry post 2020.

5.3 Collaboration

2015 finding	2016 finding	Variance	Outlook
On target	On target	No change	Medium confidence

5.3.1 Current status

Collaboration is assessed as ‘on target’. The competitive CfD scheme however continues to have a mixed impact on both vertical and horizontal collaboration which, amongst other factors, can be dependent on developer size and experience.

Progress in the number of contracting packages has moved up to ‘ahead of target’ this year. Evidence highlighted several projects that have closed with fewer than 5 packages and some reduction in contingencies, as noted by the finance community. However, evidence showed variability in the relationship between contracting packages, contingency levels and overall project cost. Certain developers with strong in-house technical expertise and interface management believe they can reduce contingencies through multiple contracting packages. For ‘bankability’ purposes developers who are finance led prefer fewer packages. They share the view that reduced financing costs (the finance community offer attractive terms for EPCI projects) outweigh those incurred through higher contingencies and risk premiums passed on by their main contractors.

Standard contracts developed specifically for the offshore wind sector have not yet materialised. Evidence did reveal examples of efficiencies achieved through the use of frameworks and more consistent approaches to contracting. Standard contracts was assessed as ‘on target’, but there is still scope for future cost reduction through contract innovation.

Knowledge sharing amongst the developer community (horizontal collaboration) was assessed as ‘on target’. Many respondents detailed participation in knowledge sharing forums and joint industry projects. Evidence this year did however reveal a trend towards lower collaboration due to the competitive CfD scheme and strong competition in bidding for pre-developed EU sites.

Supply chain involvement (vertical collaboration) was assessed as ‘behind target’, although this indicator was very close to being assessed as ‘on target’. To establish price accuracy for CfD auction bids, developers look to engage the supply chain as early as possible in a project (e.g. FEED). However, the supply chain noted variability in the method of engagement (depending on the contracting strategy and experience of the developer), with many approaches (e.g. procurement led tendering exercises) deemed insufficient to produce accurate costs and/or deliver cost reduction.

5.3.2 Outlook

In terms of contracting packages, those consulted expect a continuation of the two divergent approaches described (3 to 5 packages versus multiple packages). The 2020 CRMF milestone is based on a high portion of projects closed with less than three packages, as well as a reduction in contingencies. However both approaches appear capable of cost reduction through either favourable finance terms, or reduced CAPEX from reduced contingencies associated with tighter interface management.

Industry expressed low confidence in the development of offshore wind specific standard contracts pre 2020, with the cost reduction potential through contract innovation not expected to materialise.

There was almost universal recognition that knowledge sharing amongst competing organisations is expected to decrease in the coming years, driven by the competitive industry. Although there was recognition that collaboration in closed groups during the operations phase (post CfD) could still deliver increased efficiency and cost reduction potential.

Supply chain involvement pre-PQQ is expected to increase as knowledge sharing decreases and developers continue to seek price certainty on CfD auction bids.

6 Finance work stream

This section presents the findings of the qualitative assessment for the finance indicators.

6.1 Cost of equity

2015 finding	2016 finding	Variance	Outlook
On target	Ahead of target	Up	High confidence

6.1.1 Current status

Cost of Equity is assessed as being overall “Ahead of target”, with risk premiums continuing to fall or remain the same, and sufficient capital being available to fund construction and operations, albeit not always as early in the financing cycle as desirable.

Overall, capital available for construction and operational project funding is adequate. A number of developers and financial investors have had to retain their full equity stakes for longer than desired while deals are concluded with incoming partners and full financial close is reached. However, there were no reports of needing to source external bridging equity during the period.

The regulatory risk profile of offshore wind in the UK is believed to be generally in line with the overall risk profile for utilities. Some respondents perceive a greater risk due to focus on single generation technology, while others viewed revenues underpinned by CfD’s as reducing the risk profile relative to the wider utility sector. On the whole an asset beta of 0.6 (in line with Competition & Markets Authority report from 2015⁷) was considered appropriate.

Construction risk premium is reducing, based on qualitative feedback received. The level of risk and how it is managed is still site and project specific, with contracting approach, new turbines, difficult or unfamiliar seabed and moving further from shore being key drivers. Overall however, investors and developers are becoming more comfortable with how risks should be priced, allocated and managed.

Contingency levels for OPEX remain stable for cost-plus arrangements at roughly 15% of base case budgets and are important in determining DSCR levels. These cost-plus arrangements are, on the whole, favoured by investors as they provide potential upside if savings can be made (or contingencies avoided). Fixed-price O&M contracts continue to be favoured by lenders as they provide maximum certainty on costs and DSCR levels.

Potential risks additional to construction and operations-specific risks are seen as access to the right finance at the right time and negative pricing. However, there was no evidence that these are being priced as a premium to the cost of equity. In general, cost of equity is reducing as competition for offshore wind investment increases due to both industry development and a relative lack of alternative infrastructure opportunities.

6.1.2 Outlook

The outlook for Cost of Equity is assessed as High. Capital is expected to be attracted into the UK offshore wind sector, with confidence in the sector expected to continue to be underpinned

⁷ https://assets.publishing.service.gov.uk/media/54edfe9340f0b6142a000001/Cost_of_capital.pdf

by sufficient regulatory certainty. A number of respondents noted a tension between the “true” developer risk premium, which is probably increasing due to uncertainty on future returns (fewer auctions with substantial price competition) and the “observed” developer risk premium, which is being priced into CfD bids (due to the need to win a competitive CfD).

The view on future levels of capital availability was mixed. A number of respondents did not foresee any shortfall on construction or operational projects as such, but did expect to continue to hold their full equity stake until FID. One driver mentioned for this was the perceived misalignment between the CfD contractual delivery milestones and the timing of the FID and financial close processes. Others specifically mentioned potential difficulties in funding future development expenditure, given the uncertainty of ultimately winning a CfD; this was also expected to result in consolidation of future development work into a small number of large entities in the UK, which is in contrast with the trend for a large number of bidders for EU projects.

Regulatory risk premium will be most influenced by visibility of political support for low carbon generation and policy stability. The political framework over the near to medium term is expected to at least maintain the current risk profile.

Construction risk premium is expected on the whole to continue to decrease. Further successful project delivery and refined installation techniques may well be offset to some extent by introducing new technologies and new site conditions. However, the net result is expected to be positive.

Operating contingencies are expected to remain at a similar percentage of base cost budgets, but these underlying base case costs are generally expected to decrease. In some cases, building O&M experience and integrating more operational lessons learned into design of future windfarms are expected to reduce contingency levels.

Overall feedback indicates that in future there is even less likelihood of pricing in additional developer risk for construction and operational projects as the technology continues to evolve and offshore wind becomes an established asset class. Improved returns in other markets, including stable returns like government bonds, could divert some of the investment away from offshore wind.

6.2 Cost of debt

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target	No change	High confidence

6.2.1 Current status

Cost of Debt is assessed as “Ahead of Target”. Margins, as well as all-in costs, are tracking below the target levels, though it is proving challenging to fulfil the increasingly large funding tranches in the timeframes required.

Gearing in both construction and operational projects has increased to 70% and above. Debt finance is also being brought in at an earlier stage, with project finance coming in at FID in some cases and this level of debt finance is expected to be sustainable. Gearing for the OFTO element of projects has reached as high as 85% due to the shorter-term nature of lending.

Debt margins for both construction and operations remain ahead of target. Margins on construction debt are in the range 200-225bp for opco financing and 250-275bp for holdco level financing. Margins on operating project debt are in the range 190-200bp at the start of the loan term, rising to 240bp towards the end of the term for opco financing; and 240-250bp at the start of the loan term, rising to 270-280bp towards the end of the term for holdco level financing. As mentioned by a number of respondents, we note that, from an overall cost of finance perspective, it is the all-in rate which is important.

Some lenders have noted increasing difficulty in selling down large portions of debt within the desired timescales. This is driven by a number of factors: fewer new lenders are entering the market than previously anticipated, increased caution from lenders new to the UK market, long repayment terms are unattractive to some lenders, each project requires a larger number of parties to complete financing than in the past. At least one respondent also noted that syndication of GBP-denominated debt was more difficult than for EURO-denominated debt.

6.2.2 Outlook

The outlook for Cost of Debt is assessed as High. Offshore wind is expected to remain an attractive asset class, with current levels of gearing being maintained and new lenders entering the market, though at a slower pace than previously envisaged.

Project financing is expected to continue at the levels now being seen, with ~75% gearing appearing to be the level achievable given the amount of finance and number of lenders required for £multi-billion projects. There are also limits to the amount of debt each project can afford due to operating margins and DSCR's. This level of debt financing has potential to be a significant cost reduction lever, but there is not yet a consistent approach or appetite between project developers on using project finance.

Debt margins are expected to be relatively stable going forward, with little scope for further reductions, but also no reason to expect any increase. The size and volume of transactions means that lenders need to be encouraged into the sector, rather than being turned away by low margins. The high amounts of borrowing also mean that project owners are more likely to have to include some portion of more expensive debt in the funding mix, preventing the average margin from reducing further. The all-in cost of debt is expected to be more influenced by developments in the wider economy (e.g. Base rate movements, government bond yields) than any factors specific to the offshore wind sector.

The number of lenders active in UK offshore wind is expected to continue to increase, with more banks becoming comfortable with the technology and offshore wind becoming more of an attractive asset class. This has been aided by a growing track record of successful project delivery. This will continue to improve capital availability, although the entry of new lenders to the sector may be slower than previously envisaged. While improvements in the number of opportunities and returns available from other infrastructure assets could potentially divert some funding, offshore wind is generally considered to be sufficiently mature to remain an attractive asset class.

6.3 OFTO Tender Revenue Stream (TRS)

2015 finding	2016 finding	Variance	Outlook
N/A	Ahead of target	N/A	High confidence

6.3.1 Current status

The OFTO Tender Revenue Stream indicator is assessed as “Ahead of target”. This indicator was added for the 2016 CRMF in order to track the ratio of OFTO TRS to transmission assets transfer value. This ratio is driven by competition between OFTO’s and their abilities to operate the transmission assets cost effectively. The metric has seen continued reductions from in excess of 14% for licences granted in 2011 to an average of 7% for licences granted in 2016, with individual licences granted in 2015 and 2016 at a ratio lower than 7%

6.3.2 Outlook

The outlook is assessed as High. Competition in the sector is expected to continue to increase, potentially driving returns even lower. Some concern was noted that generators are felt to carry a disproportionate share of risk when compared to penalties on OFTO’s for availability levels. Any moves to re-align the allocation of risk could have the effect of increasing OFTO return requirements, but this may then be offset by reduced return expectations on the side of the generator owners and insurers.

6.4 Insurance

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target	No change	Medium confidence

6.4.1 Current status

This indicator is assessed as “On target” for 2016 compared to “Ahead of target” in 2015. Construction phase insurance premiums have remained relatively stable, while operations phase premiums have reduced from 2015.

The construction phase insurance indicator focuses on Construction All-Risks (CAR) insurance. However, there are other insurance types relevant to the construction phase, including Third Partly Liability (TPL) and Delayed Start-Up (DSU).

Increased competition in the insurance market is perceived to have led to a slight overall reduction in the cost of construction insurance, with insurers often having to accept terms imposed by project owners. Some respondents note that it is difficult for inexperienced companies to forecast the frequency and severity of claims especially if they have only been exposed to the early stages of the project life cycle where major problems are less likely. This is one of the drivers of CAR premiums showing little variation through the year in spite of differences in project risks and specifics of cover. Premiums in the range £35 - £44k per MW have been quoted for 2016, but remain dependent on a number of factors including absolute capex values, turbine type (new or more mature), experience of main contracting parties, project schedule and size of deductible.

The operations phase insurance focuses on Operations All-Risks (OAR) insurance. However, there are other insurance types relevant to the construction phase including, significantly in some cases, Business Interruption (BI) insurance.

Operating insurance premiums are generally more variable than those for construction. This is driven primarily by different operators preferring different levels of deductible, export cable failures and continued lack of comfort on the apportionment of risk between generators and OFTO's. Other factors include maintenance and business continuity plans, location and availability of vessels. Premiums for OAR in the range £10 – £13 per kW have been quoted. Respondents also note that insurance costs for renewals tend to be higher as turbines come out of warranty and plant ages, but this can be offset by confidence gained from the operating life to date. Ongoing issues around export cables mean generators are increasingly likely to purchase BI insurance.

6.4.2 Outlook

The outlook for Insurance has a Medium confidence. Current levels of competition in the insurance market are expected to continue, with potential for further cost reductions as operators and insurers build experience. The generator-OFTO relationship and export cable availability issues are set to remain key areas for concern.

Supply and demand for construction insurance should remain in-step, with growth in the offshore wind industry matched by additional entrants into the insurance market. Some rate cutting seen at present is not expected to be sustainable, but there is sufficient appetite among insurers to ensure rates remain competitive. Unless there are major issues leading to insurance losses in the industry, factors in the wider insurance market are expected to more of a driver of costs.

Premium levels for operations insurance are influenced (among other things) by lack of claim experience. Lack of data means premiums can be pushed higher due to risk uncertainty. As the industry matures and data availability improves, premiums can be priced to more accurately (and lower) reflect the risks covered. The main barrier to this would be failure to address ongoing export cable failures, which could lead to major losses and/or drive players out of the market.

7 Industry challenges and risks

A number of challenges and risks to industry progress were identified in this analysis:

Sustaining cost reduction post 2020

The sector has made very good progress and the trajectory for cost reduction has been higher than originally anticipated by the pathways study, with many of the CRMF targets achieved ahead of schedule. However, the industry is still evolving with future scenarios anticipating larger turbines, installed in deeper waters on a variety of support structure concepts, further from shore. The industry is also sensitive to external market forces, such as the cost of steel, oil price, and macro-economic factors that affect insurance premiums and finance.

To sustain a cost-competitive offshore wind power industry, Government and industry stakeholders must develop a coordinated route to further cost reduction post 2020.

Sustainability of the supply chain

Increased competition has reduced supply chain margins and had a more significant impact on projects costs than originally anticipated. Forced to offer lower prices, there has been a high degree of supply chain consolidation. However, a number of organisations consulted expressed concerns about the sustainability of these prices and the resilience of the companies offering them, particularly those who are predominantly dependent on the offshore wind market.

The sustainability of low supply chain margins in a market with some uncertainty on future pipeline should be considered in future plans for cost reduction post 2020.

Developer collaboration

The increasingly competitive market, driven by the CfD scheme, has reduced incentives for horizontal collaboration between developers; collaboration that in the past years has helped to overcome some of the biggest innovation challenges facing the sector. A number of challenges still exist which would benefit from an industry wide approach, such as the management of turbulent loads and their impact on component fatigue life, and the implementation of wind farm wide control.

There is a risk that the drive for cost reduction has minimised the capacity of the industry to work together on solving issues which may have long term cost implications. Finding ways to work collaboratively on key issues will be a challenge for the industry under the current CfD scheme.

8 Conclusion

The CRMF 2016 qualitative assessment provides evidence to support the conclusions of the Quantitative Assessment that the offshore wind industry has met the 2020 LCOE Industry Target £100/MWh ahead of forecasts.

The main drivers of LCOE reduction identified by the 2016 study have been:

- Significantly reduced CAPEX through faster than anticipated progress in turbine rating;
- Reduced construction costs driven in part by reduced vessel rates as a result of oversupply and the downturn in the oil and gas sector;
- Increased use of innovative technology, such as 66kV array cables and lightweight and novel substation solutions, as well as an increase in demonstration sites for new and innovative technologies;
- Lower supply chain costs due to increased competition amongst contractors;
- Lower overall project costs due to increased competition between developers;
- Lower project financing costs (equity and debt) and lower insurance costs attributed to a maturing sector with lower perceived risk.














































The key recommendations for industry to achieve further cost reduction are:

- Build on current momentum and develop a robust and deliverable cost reduction plan for post 2020;
- Develop mechanisms for developer collaboration which ensure the benefits of industry knowledge sharing are continued without damaging competitive advantage;
- Explore best practice policy and regulatory frameworks from countries that have reduced risk and enabled low winning bid prices.

With industry targets for cost reduction achieved ahead of schedule, the UK government should increase efforts to maximise the UK benefits from offshore wind through the development of a targeted industrial strategy and increased support for UK content in the supply chain.

Appendix 1 Level 3 indicator scores

Level 1 indicator	Level 3 indicator	Cost reduction potential weighting	L3 2015	L3 2016	Variance	Outlook (confidence)
Project Management and Development	FEED (optimisation and use of multi-variable array layout tools)	1.30%				High
Project Management and Development	Development phase project management	0.50%				High
Project Management and Development	Floating lidar	0.10%				High
Turbines	Rating	8.50%				High
Turbines	Drive train concept	2.30%				Medium
Turbines	AC power take off design	0.70%				Medium
Turbines	Optimisation of rotor diameter to rated capacity	1.20%				Medium
Turbines	blade design and manufacture	2.90%				Medium
Turbines	Control	2.40%				Medium
Turbines	Integrated design (of turbine and support structure)	1.00%				Low
Turbines	Turbine design	0.50%	N/A			High
Balance of Plant	66kv	0.15%				Medium
Balance of Plant	Improvement in array cable standards and spec	0.10%				Medium
Balance of Plant	Extended (XL) monopiles and improved design standards	1.60%				Medium
Balance of Plant	Novel monopile design concepts	0.30%	N/A			Medium

Balance of Plant	Optimised Jacket design and manufacture	1.50%				Medium
Balance of Plant	Suction bucket	0.30%				Medium
Balance of Plant	GBS support structures	0.10%	N/A			Low
Transmission CAPEX	Standardisation of offshore AC substation	1.10%				Medium
Transmission CAPEX	Lightweight or novel offshore substations	1.10%	N/A			High
Transmission CAPEX	Overplanting and/or use of dynamic rating	0.80%				High
Transmission CAPEX	Increased capacity export cables	0.10%	N/A			Medium
Transmission CAPEX	Booster stations (additional platforms midway to shore, to reduce reactive power problem for AC transmission)	0.30%				High
Transmission CAPEX	Compact HVDC systems	0.20%				Low
Installation	Lifting conditions for blades	0.10%				High
Installation	Feeder vessels	0.10%				Medium
Installation	Improvements in the installation process for monopiles through better vessels	0.20%				Medium
Installation	Improvements in operational weather windows for monopile installation	1.00%				High
Installation	Purpose built jacket installation vessels	0.40%				Low
Installation	Flexible sea fastenings	0.20%				Medium
Installation	Optimised cable pull in and hang off processes	0.30%				Medium
Installation	Improvements in operational weather limits for cables	0.25%				High

Installation	Optimised cable installation vessels and tooling	0.40%				Medium
O&M	Turbine Condition based maintenance	0.60%				Medium
O&M	Access from vessel to turbine	0.60%				High
O&M	Access from shore to site	0.20%				High
O&M	Inventory management	0.10%				Medium
O&M	Offshore crew accommodation	0.10%				Medium
O&M	Transmission asset O&M	0.10%				Medium
Increased design life	Increased design life	3.00%				High
Growth and Scale	UK market	0.45%				Medium
Growth and Scale	EU market (including UK)	0.91%				Medium
Growth and Scale	UK content	N/A	N/A	N/A	N/A	Medium
Competition	Competition in turbine supply	3.57%				Medium
Competition	Competition in support structure supply	0.71%				Medium
Competition	Competition in HV topside equipment supply	0.40%				High
Competition	Competition in HV cable supply	0.40%				Medium
Competition	Competition in Turbine Installation	0.50%				High
Competition	Competition in Foundation Installation	1.64%				High
Competition	Competition in Cable Installation	0.93%				High
Collaboration	Contracting packages / interface management	1.90%				Medium
Collaboration	Supply chain involvement	1.90%				Medium

Collaboration	Standard contracts	0.53%				Low
Collaboration	Knowledge sharing	0.53%				Medium
Collaboration	Technical standards	0.53%				Medium
Cost of equity	Capital Availability - Bridge Equity (Construction) (% of total funding)	1.00%				Medium
Cost of equity	Capital Availability - Bridge Equity (Operation) (% of total funding)	1.00%				High
Cost of equity	Regulatory risk premium / asset beta (Asset beta)	1.00%				Medium
Cost of equity	Construction specific risk premium (P90 contract value multiple)	1.00%				Medium
Cost of equity	Operations risk premium (P90 risk premium)	1.00%				High
Cost of equity	Developer risk premium (% premium)	1.00%				Medium
Cost of debt	Gearing - construction (% of total funding)	0.56%				High
Cost of debt	Gearing- operations (% of total funding)	0.56%				High
Cost of debt	Construction debt margin (basis points margin, bps)	0.56%				High
Cost of debt	Operations debt margin (basis points margin, bps)	0.56%				High
Cost of debt	Capital Availability - Debt syndication	0.56%	N/A			High
Insurance	Construction phase insurance	0.35%				Medium
Insurance	Operations phase insurance	0.35%				Medium
OFTO Tender Revenue Stream (TRS)	OFTO Tender Revenue Stream (TRS)	0.50%	N/A			High

Table 3 CRMF 2016 qualitative assessment level 3 scores

Appendix 2 CRMF evidence log

Report available at <http://ore.catapult.org.uk/crmf>

Appendix 3 CRMF quantitative assessment

Report available at <http://ore.catapult.org.uk/crmf>

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