Evidence Log

CRMF 2016

January 2017

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1 Introduction

This document contains evidence collected as part of the Cost Reduction Monitoring Framework (CRMF) qualitative study 2016.

1.1 Acknowledgements

It would not have been possible to conduct this study without the valuable contributions of several parties, ORE Catapult specifically acknowledge:

- OWPB and The Crown Estate as project sponsors;
- RenewableUK who contributed information and data from their 'Offshore Wind Project Intelligence Database'. See http://www.renewableuk.com/page/ProjectIntelligence for more information;
- All of the organisations and contacts who gave their time and input voluntarily by completing questionnaires or participating in interviews.

1.2 Evidence gathering

This document provides details of evidence collected as part of the qualitative study of CRMF 2016. Evidence was collected by three primary methods:

1. Questionnaires. Participants were sent a link to an online questionnaire where they provided answers to specific questions with free text fields and also ratings of confidence in future outlooks on a defined scale. Follow up discussions on some feedback were conducted where clarification of specific responses were required.
2. Interviews. Participants were engaged in direct interview either in person, by video or telephone conferencing. Interviews were conducted by at least two ORE Catapult staff, in some cases with a single point of contact and in others with multiple participants. Interviews typically lasted between 1 and 2 hours.
3. Market intelligence. Using both publically available data and market intelligence provided by other organisations an understanding of the current state and likely future outlook for particular indicators was developed.

1.3 Milestones and assessment

This document provides details of all indicators assessed as part of the qualitative study. Each indicator has a description of what 'ahead of target', 'on target', 'behind target' or 'missed target' is classified for each year to 2020. These milestone scorecards were key in guiding assessment of progress to cost reduction contributed by each indicator.

Some milestones have were revised following feedback and review of CRMF 2015 findings. There are indicators which have been removed, consolidated from several to one single

indicator, split from a single indicator into two distinct indicators and some new indicators have been added. All changes have been made with both considerations of the relevance of indicators to current industry trends, but also an attempt to maintain consistency with previous studies to enable objective comparison of progress from year to year as far as possible.

Assessment of each indicator was conducted in a series of workshop discussions where evidence collected was appraised by suitably experienced multi-disciplinary teams.

1.4 Outlooks

In addition to assessment of the recent progress of indicators based on evidence collected during engagement participants were also asked to provide their confidence that the vision for 2020 cost reduction to be achieved by the indicator would be realised. Participants could rate their confidence, from low to high on a scale of 1 – 4. This forward looking metric is inherently more subjective than the largely evidence based assessments of ‘on target’ etc. As such it should not be considered to have the same weight as the more rigorous milestone progress assessment.

1.5 Notes on evidence

It is important to consider some key points when reviewing the evidence presented in this document.

Individual pieces of interview and questionnaire evidence was rated by participants as falling into one of three categories:

1. Public: information which could be freely quoted (generally press releases etc.);
2. Private: information which could be reproduced in an anonymised form;
3. Commercial in confidence: information which could be used to shape understanding but which would not be published in any form.

Participants provided along with their responses an indication of the level of confidentiality of the information provided. Accordingly significantly more evidence than it is possible to present in this public document was used as assessment of progress.

The complied evidence log has been anonymised by ORE Catapult, specifically to remove Project, Product, Company, Site or otherwise potentially commercially sensitive information. Where ORE Catapult have edited contributions [square brackets] have been used to highlight the change to the reader. The reader is provided with broad groupings which give an indication of the type of organisation which has contributed a particular response.

Nomenclature, definitions, jargon or spellings used in contributions have, on the whole, not been modified by ORE Catapult. This should be noted when making comparisons. For example what one party considers ‘near shore’ may not be the same distance as another. Where edit

has been required to aid the reader, adjustments that have been made by ORE Catapult are again identified by [square brackets].

Evidence from the questionnaire and interview has been provided by a broad spectrum of organisations of varying sizes operating across the offshore wind market. The evidence presented as a result of direct engagement (questionnaire or interview) has been provided by organisations in the following categories:

- Blades OEM;
- Designers;
- Developers;
- Electrical;
- Finance;
- Foundations;
- Installation;
- Insurance;
- Lidar;
- O&M;
- Survey;
- WTG OEM.

The evidence presented has been built up as a result of direct engagements through questionnaire and interview, in combination with review workshops, OWPB subject matter sub-groups and validated by ORE Catapult internal knowledge and experience.

Evidence and summaries presented do not necessarily represent the opinion or policies of ORE Catapult, and have been informed by our engagement with industry and the available evidence.

2 List of abbreviations

- AEP: Annual energy production
- BLEEP: Blade leading edge erosion programme
- BoP: Balance of plant
- CBM: Condition based maintenance
- CFD: Computational fluid dynamics
- CfD: Contract for difference
- CMS: Condition monitoring system
- CRMF: Cost reduction monitoring framework
- CRP: Cost reduction pathways
- CTV: Crew transfer vessel
- EoW: End of warranty
- EPCI: Engineering procurement construction and installation
- FEED: Front end engineering design
- FID: Final investment decision
- FiT: Feed in tariff
- GBS: Gravity base structure
- HLV: Heavy lift vessel
- IMCA: International Marine Contractors Association
- ITT: Invitation to tender
- KSF: Knowledge sharing forum
- LCCC: Low carbon contracts company
- LCOE: Levelised cost of energy
- LEC: Levy exemption certificates
- O&M: Operations and maintenance

- OEM: Original equipment manufacturer
- OFTO: Offshore Transmission Owner
- OSS: Offshore sub-station
- OWA: Offshore wind accelerator
- OWPB: Offshore wind programme board
- OWIC: Offshore wind industry council
- PPE: Personal protective equipment
- PQQ: Pre-qualification questionnaire
- ROV: Remotely Operated Vehicle
- TCE: The Crown Estate
- TRL: Technology readiness level
- WTG: Wind turbine generator
- WTIV: Wind turbine installation vessel

3 FEED (optimisation & use of multi-variable array layout tools)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Project management and development	Project management and development	FEED (optimisation & use of multi-variable array layout tools)

3.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as on target in 2016 because there is evidence of the supply chain being sufficiently involved in the FEED process to enable some cost reductions. There is also a recognition by developers, designers and the supply chain that multi variable layout optimisation is important, with some gestures towards a more integrated approach but an over-riding impression from almost all consultees that there is the opportunity to do more in this area in the future.

In CRMF 2015 this indicator was also assessed as ‘on target’, with particular comment around the level of supply chain involvement being less than optimal, and the tension between delivering detailed work pre-CfD award and the need for the supply chain to commit in shorter timescales.

It would appear that as the challenges of the competitive auction support process are here to stay both developers and their suppliers now appreciate their situation and are finding ways to work successfully in this new market structure. There has also been continued work on individual areas related to this stage of development, for example in refining wake modelling tools.

Outlook:

There was consistent comment during engagement suggesting that there remains both technical and commercial space for projects to do more in this area and unlock further cost reduction. Future developments with either software tools or greater collaboration or both are possible and it seems that there is continued appetite to innovate and apply both new techniques and find an optimum balance of when work is completed based on auction support.

A ‘high confidence’ was expressed by the industry, with cautious optimism probably a justifiable future outlook for this indicator as it looks likely that a rating of ‘on target’ is achievable in 2020.

3.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Improved FEED studies with greater input from supply chain. Computer design tools used that assist with the optimisation of the wind farm layout, considering multiple variables including yield, ground	More detailed FEED design studies optimising at system level, with input from component designers and installers. Computer design tools used that assist with the optimisation of the wind farm layout, considering multiple	More detailed FEED design studies optimising at system level, with input from component designers and installers. Computer design tools used that assist with the optimisation of the wind farm layout, considering multiple	More detailed FEED design studies optimising at system level, with input from component designers and installers from early in project development. Computer design tools used that assist with the	More detailed FEED design studies optimising at system level, with input from component designers and installers from early in project development. Computer design tools used that assist with the

	conditions and cable lengths.	variables including yield, ground conditions and cable lengths.	variables including yield, ground conditions and cable lengths.	optimisation of the wind farm layout, considering multiple variables including yield, ground conditions and cable lengths.	optimisation of the wind farm layout, considering multiple variables including yield, ground conditions and cable lengths.
On target	Improved FEED studies with input from supply chain. Some optimisation of site layout based on multi-variable modelling, with limited verification of models.	Improved FEED studies with greater input from supply chain. Good progress in optimising site layout based on multi-variable modelling, with limited verification of models.	Improved FEED studies with greater input from supply chain. Computer design tools used that assist with the optimisation of the wind farm layout, considering multiple variables including yield, ground conditions and cable lengths.	More detailed FEED design studies optimising at system level, with input from component designers and installers. Computer design tools used that assist with the optimisation of the wind farm layout, considering multiple variables including yield, ground conditions and cable lengths.	More detailed FEED design studies optimising at system level, with input from component designers and installers from early in project development. Computer design tools used that assist with the optimisation of the wind farm layout, considering multiple variables including yield, ground conditions and cable lengths.
Behind target	Some improvements in FEED studies. Some optimisation of site layout based on multi-variable modelling, with	Improved FEED studies with input from supply chain. Some optimisation of site layout based on multi-variable	Improved FEED studies with input from supply chain. Some optimisation of site layout based on multi-variable	Improved FEED studies with greater input from supply chain. Good progress in optimising site	Improved FEED studies with greater input from supply chain. Computer design tools used that assist with the

	limited verification of models.	modelling, with limited verification of models.	modelling, with limited verification of models.	layout based on multi-variable modelling, with limited verification of models.	optimisation of the wind farm layout, considering multiple variables including yield, ground conditions and cable lengths.
Missed target	No improvements	Some improvements in FEED studies. Some optimisation of site layout based on multi-variable modelling, with limited verification of models.	Some improvements in FEED studies. Some optimisation of site layout based on multi-variable modelling, with limited verification of models.	Improved FEED studies with input from supply chain. Some optimisation of site layout based on multi-variable modelling, with limited verification of models.	Improved FEED studies with input from supply chain. Some optimisation of site layout based on multi-variable modelling, with limited verification of models.

3.3 Evidence

3.3.1 Questionnaires

Category	Questionnaire response
Describe any improvement in FEED studies which you have seen over the past year. Provide specific examples where possible.	
Designer / Survey	We are seeing better use of the survey data with greater integration to manage the ground risk particularly as CFD and other auctions demonstrate the OWF costs are falling.

[Developer]	In house expertise commonly used to coordinate FEED studies with input from the supply chain. [Developer] don't use a proprietary site design tool for this, rather undertake iterative multi-disciplinary design processes to scope out key elements of the project. Competitive market has led to more aggressive use of new technology developments e.g. 66 kV, aggressive monopile optimisations
[Developer]	With more operational data across the industry, there has been a gradual reduction in uncertainty of wind resource and assessment of wake effects More construction and operational data and improved I&L and O&M tools has led to more optimised I&L and O&M logistics set-up Industry tools are becoming more standardised, e.g. for electrical system studies, enabling more efficient sharing of data Increased commercial data from previous tenders means design choices are more informed Continuous improvement as lessons learnt are transferred from one project are passed to the next, e.g. experiences from jacket design and fabrication at [PROJECT] passed to [PROJECT], electrical platform designs are evolution of previous generations
Describe how the supply chain is involved in the design of offshore wind farms	
Designer / Survey	[COMPANY] provide all types of data to the OWF business during feasibility and design stage, this data enables clients to assess and manage the foundation risk and risks associated with cable installation.
[Developer]	Supply chain involved in FEED throughout. FEED commonly runs in parallel with competitive tendering and competitive FEED as part of the tendering process has been deployed in the past to co-develop designs. Early works agreements has been used in the pre-contract stage once preferred suppliers are identified to further refine the FEED and basic designs.

[Developer]	The supply chain is engaged from the outset of project development, for example in pre-tender meetings to understand the technology options, including the next generation or new innovative solutions. The supply chain companies, particularly Tier 1, are invited to comment on preliminary designs or submit their own outline proposals using site data provided, e.g. • Foundation fabricators have reviewed foundation options from a fabrication perspective • Installation contractors have reviewed foundation options from an installation perspective and provided operating limits • Potential foundation suppliers have priced concept solutions • Electrical contractors have submitted outline electrical configurations and OSS solutions The tendering process is implemented in parallel with FEED and detail design activities, so options are included in the scope, to ensure the most cost-effective solutions are finally selected. There are limitations on the detail of the discussions with suppliers during tendering because a large number of suppliers are usually involved, each offering different equipment specifications, design solutions or methods of installation. There is also reluctance on the part of suppliers to carry out significant detail design work until contract award. As contract award usually occurs quite close to material orders, there is less opportunity than desired for detailed design optimisation.
At what point in the design process does the supply chain become involved?	
Designer / Survey	[COMPANY] is involved at an early stage during feasibility and site selection.
[Developer]	Supply chain engagement is key throughout project development from concept to O&M.

[Developer]	Informally from outset, e.g. pre-tender meetings. Formally, after contract award, e.g. turbine supplier engages in foundation design process after contractual commitment is made
Discuss whether you think the supply chain are more involved in the design of wind farms than three years ago.	
Designer / Survey	There is more involvement which is probably contributing to the cost reduction.
[Developer]	Approach to supply chain engagement has been consistent within [Developer] for the past 3 years. Competitive markets has seen move towards more collaborative approach. With early preferred supplier selection
[Developer]	Not more involved, but now more experienced in delivery of offshore wind farms and perhaps more engaged with philosophy of driving down LCOE.
Describe any planned future changes to the design process that may impact LCOE.	
Designer / Survey	[COMPANY] is involved with updating pile design methods to take account of the increased pile dimensions.
[Developer]	Much more aggressive use of new technology and unproven designs. Design process for competitive sites likely to be based on significantly smaller teams to reduce upfront spend prior to confirmation of route to market.
[Developer]	Increasing data and experience makes design tools increasing more effective. We have tested various optimisation tools but it is very difficult to incorporate all parameters into a single layout tool. Instead, we will continue to develop a series of in-

	house tools to assess different parts of the windfarm. The key is to build a robust financial model and obtain accurate input data, in particular good price estimates.

3.3.2 Interview

Category	Interview response
Which modelling tools do you use to support your FEED study? Do any of these tools enable the optimisation of layout for multiple variables, for example yield, ground conditions and cable lengths?	
[Designer]	With respect to multi-variable array layout/project design tools, not much has changed since last year. There are lots of 'point-of-view' tools for cable routing, wake effects, site investigation etc. but outputs from these tools tend to come together separately rather than being run in parallel.
[Developer]	Multi variable layout optimised is a good example of where [Developer] haven't done much so far, projects so far do not have the level of complexity that would necessitate multi variable layout optimisation, do not wish to comment much. [Developer] do see a difference in the approach that they have had towards supply chain involvement. For example at [PROJECT] had very little involvement of supply chain ahead of FID, whereas at [PROJECT] more recently they had deliberately engaged two contractors, and paid for 2 designs ahead of FID and only moved to a preferred contractor very close to FID. This represents and acknowledgement that it may offer better value for the project overall to incur some additional cost upfront by allowing more advanced designs ahead of FID.

	This could mean a larger upfront spend, but it offers benefits to make FID much easier and helps with timescales on the project delivery.
[Developer]	Optimising site layout. For example, not installing turbines in straight lines (visual impact optimised) to yield optimised for windfarms far offshore (slides attached) Continued learnings as a result of a predictable pipeline of projects across the portfolio

3.3.3 Market intelligence

Evidence	Source
• On 11/05/16 The Department of Mechanical Engineering of KU Leuven proposed a method of Wind-farm layout optimisation using a hybrid Jensen–LES approach. They propose an optimisation approach that is based on a hybrid combination of Large-Eddy Simulations (LES) and the Jensen model, in which optimisation is mainly performed using the Jensen model, and LES is used at a few points only during optimisation for online tuning of the wake-expansion coefficient in the Jensen model, and for validation of the results.	http://www.wind-energ-sci-discuss.net/wes-2016-15/wes-2016-15.pdf

3.4 Additional comments

None for this indicator

3.5 Recommendations

None for this indicator

4 Site investigation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Project management and development	Project management and development	Site investigation

4.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	On target	⇧	High confidence

Finding: On target

Marked as ‘on target’ for 2016 as there is general consensus in the industry, supported by evidence that the level and quality of site investigations are increasing. A key driver of a change in site investigation scope has been suggested to be the downturn in the oil and gas market which has significantly reduced survey costs and allows developers to get more information for the same price. It was not possible to score this indicator as ‘ahead of target’ as it is unlikely that the optimum amount of site investigation is being completed on UK projects, as there remains a significant reluctance to spend money on site investigation whilst at risk of consent and CfD award.

Last year this indicator was assessed as behind target, as there was little evidence suggesting consistent improvements across the industry in the quality of site investigations and the supply chain did not report any improvements in data provision.

Despite the suggestion of a marked improvement over the last 12 months the progress in this indicator is tempered by the way in which suppliers are able to utilise site investigation information to inform their designs. There are fundamentally different approaches taken by different developers, and the way in which they chose to interact with the supply chain, including how and when they are involved in projects means that although there has been an evidenced improvement in site investigation the requirement in this indicator for 'Information to be used in suppliers' designs is something that happens to significantly varying degrees across the industry.

Outlook:

The future outlook for this indicator is mixed.

On the one hand, whilst other markets are depressed it is likely that a surplus of survey contractors will continue to be keen to work in the sector and as a result cost reduction through low rates will be achieved. Of course this cost reduction benefit is not in the control of the offshore wind industry, and could in theory change rapidly in future.

The nature of support for projects will continue to be by competitive CfD for at least the medium term in the UK and as such the chances are that an optimal level of pre FID site investigation as demonstrated on recent aggressively priced European development projects will not be achieved by projects in the UK.

Some continued gradual improvement in the application of site investigation may be naturally expected as the pool of experience grows and the number of developers who have experienced the potential for site investigation data to mitigate future project costs increases. Related to this, experience in balancing the needs for site investigations to inform designs and the cost of work at risk will naturally increase as more projects are developed.

A 'high confidence' was expressed by the industry, which on balance is probably reflective of the high likelihood of achieving the 'on target' milestone in 2020.

4.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Optimum amount and coverage of surveys now understood and applied. Information being used in suppliers' designs.	Optimum amount and coverage of surveys now understood and applied. Information being used in suppliers' designs.	Supplier designs optimised based on increased level of geotech and geophysical surveys with greater surveying of cable route and landfall. 70% of potential benefits captured for a typical project.	Supplier designs optimised based on increased level of geotech and geophysical surveys with greater surveying of cable route and landfall. 80% of potential benefits captured for a typical project.	Supplier designs optimised based on increased level of geotech and geophysical surveys with greater surveying of cable route and landfall. 90% of potential benefits captured for a typical project.
On target	Increased surveying of site, cable route and landfall. Information being used in suppliers' designs.	Greatly increased surveying of site, cable route and landfall. Information being used in suppliers' designs.	Optimum amount and coverage of surveys now understood and applied. Information being used in suppliers' designs.	Optimum amount and coverage of surveys now understood and applied. Information being extensively used in suppliers' designs.	Supplier designs optimised based on increased level of geotech and geophysical surveys with greater surveying of cable route and landfall. 70% of potential benefits captured for a typical project.
Behind target	Increased surveying of site, cable route and landfall.	Increased surveying of site, cable route and landfall. Information being	Greatly increased surveying of site, cable route and landfall. Information	Optimum amount and coverage of surveys now understood and	Optimum amount and coverage of surveys now understood and

		used in suppliers' designs.	being used in suppliers' designs.	applied. Information being used in suppliers' designs.	applied. Information being extensively used in suppliers' designs.
Missed target	Recognising the opportunity for additional surveys missed	Opportunity for additional surveys mainly missed by FID 2017 projects	Increased surveying of site, cable route and landfall.	Increased surveying of site, cable route and landfall. Information being used in suppliers' designs.	Increased surveying of site, cable route and landfall. Information being used in suppliers' designs.

4.3 Evidence

4.3.1 Questionnaires

Category	Questionnaire response
How do you survey the cable route and landfall?	
Designer / Survey	Offshore cable routes are surveyed using geophysical vessels, these also typically can handle the geotechnical sampling and testing equipment. For the landfall often a separate vessel with shallow draft is required. We have also developed geophysical techniques which can span the land/marine interface. For landfalls which require HDD deeper geotechnical data is generally required which need drilling equipment. This is generally provided with a jack-up platform.

[Developer]	(To determine route before detailed route surveys). Onshore- OS maps, walking, existing services, maps. Offshore- Admiralty charts, AIS observations of shipping routes, kis-orca (existing pipe line and cable owners maps). Basic bathymetry.
[Installation]	Don't tend to do landfalls any more - cable route is typically surveyed using ROVs or vessel mounted equipment (e.g. CodaOctopus)
[Developer]	Bathymetry Sidescan sonar Magnetometer Shallow CPTs Boreholes at the landfall
Describe any recent changes to the way in which geotechnical and geophysical data are collected.	
[Foundation]	No input
Designer / Survey	Geotechnical and geophysical methods are well proven but some improvements are being made to provide enhanced geophysical data particularly at the turbine locations. UXO survey methods have been improved to increase the spacing of survey lines but still obtaining 100% data coverage.

[Developer]	Enhanced use of ground modelling to maximise use of geotech info & reduce upfront spend. Anticipated reduction in expensive SI (eg boreholes) to prefer more geophys and cpt info). Much more detailed geophysical survey in particular with more refined route finding during survey and more on board processing of data. Less diving of obstructions and much more ROV work instead. Geotechnical surveys have remained similar. Approach is highly dependent on site conditions, however enhanced use of ground modelling to maximise use of geotech info & reduce upfront spend may be anticipated. Anticipated reduction in expensive SI (e.g. boreholes) to prefer more geophys and cpt info) particularly in advance of bids.
[Installation]	Slow shift away from ROVs to vessel mounted equipment and/or AUVs. But it is early days yet.
[Developer]	Geotechnical data collected is collected in a staged approach with an additional campaign post-CfD award/post-FID. This has reduced overall survey requirements and provided an opportunity to revisit areas of potential risk or gaps in understanding of ground conditions. It also delays expenditure until more project certainty is achieved. This revised approach is dependent on reasonable uniformity of site conditions and adoption of a detailed ground model. Some sites required more detailed investigation at all turbine positions.
Explain whether you think the quality of site investigation, particularly geotechnical data, has improved over the last year and whether you are able to use this to improve your designs or service offering.	
[Foundation]	No input
Designer / Survey	Greater use is being made of the soil tests to measure the dynamic soil properties which can then lead to better understanding of pile behaviour and therefore reduce pile length and steel thickness.
[Developer]	No noticeable improvements in geotechnical data over the last year.

[Developer]	Improvement in quality from narrower specification, more selective of Contractors and Consultants, more QA control
Has the level/scope/resolution of surveys increased over the past year?	
[Foundation]	No input
Designer / Survey	Scope is probably the same but clients and contractor/consultants are making better use of the data to manage risk.
[Developer]	Yes, see question [above]
[Installation]	This tended to be specified by clients - so survey contractors just did what was asked of them.
[Developer]	Overall reduced scope as the aim has been to collect minimum possible data at each project stage to allow design to be progressed.

4.3.2 Interview

Category	Questionnaire response
Describe any recent changes to the way in which geotechnical and geophysical data are collected.	

[Installation]	In general, site data collected has improved for current projects in development across Europe compared to previous years
Explain whether you think the quality of site investigation, particularly geotechnical data, has improved over the last year and whether you are able to use this to improve your designs or service offering.	
[Installation]	Data provided to [Installation] as part of the tender process has improved in both volume and quality. Good comprehensive reports on site conditions at specific turbine locations have been provided, whereas on past projects the data has been more generic across the wind farm.
[Installation]	Developers have seen that spending money up front on site investigations has benefits during contracting as they can guarantee site condition reports at specific jack-up locations before contracts are signed.
[Designer]	Over the past couple of years there has not been much change in Europe with respect to site investigation in terms of use of new technologies and data management processes. There has been a recognition that the biggest risk to projects are those related to ground and soil conditions. As a result, post CfD and pre FID phase 2 ground investigations are now fairly comprehensive and detailed in order to accurately determine the final costs of the project build. Expertise and capability in site investigation is a good export opportunity for the UK in support of developing international offshore wind markets.
[Developer]	Survey and data collection on projects to date have all been pretty different across projects that [Developer] as a developer have worked on so far. Different sites have demanded different soil investigations. On [PROJECT] project have gone through a very detailed soil investigation, for example first campaign end of 2014 followed by full borehole campaign in 2015, so the specific foundation requirements were considered in the site investigation.

	It seems that the level of site investigation which is required or appropriate is closely linked to choice of foundation type.

4.3.3 Market intelligence

Evidence	Source
• On 03/01/16 The Department of Mechanical Engineering, University of Colorado and the National Renewable Energy Laboratory published a study titled: "Adjoint Optimization of Wind Farm Layouts for Systems Engineering Analysis". They developed an optimisation tool (WindSE) that optimizes wind turbine locations and axial induction factors as part of the National Renewable Energy Laboratory's open source wind energy systems engineering software tool WISDEM.	http://tesla.colorado.edu/attachments/team/Peter-Hamlington/King_AIAA_2016.pdf

4.4 Additional comments

None for this indicator

4.5 Recommendations

None for this indicator

5 Development phase project management

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Project management and development	Project management and development	Development phase project management

5.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ for 2016 because there is evidence suggesting that development phase project management systems are comprehensive and well adapted to offshore wind. Developers suggest that whilst these management systems are not always necessarily bespoke or developed solely for offshore wind they are something that has seen considerable effort and that systems are delivering to meet the requirements of offshore wind projects.

Last year this indicator was also marked as ‘ahead of target’ noting that all developers are highly likely to have appropriate development phase systems in place due to the scale of projects being developed.

Other trends that are relevant here and corroborate the evidence of continued strong progress is the active interest from several developers in tools to compliment the way structured collaborative projects can be executed. Specifically there is an interest in the advantages that BIM is offering to other infrastructure projects and in exploring ways to leverage these benefits for offshore wind.

Outlook:

The outlook for this indicator is positive, with the requirements of the 2020 vision arguably already met. There is no evidence to suggest that this will change for the worse in coming years.

A ‘high confidence’ was expressed by the industry for this indicator, it is clear that the industry still see and are hence working on continual gradual improvement is expected.

5.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Majority of developers have specific offshore management system with effective risk and change management systems	All major developers have specific offshore management system with effective risk and change management systems. They plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from	Effective project, change and risk management tools and procedures in place including offshore wind specific management systems, comparable to the oil and gas sector. All developers plan a framework enabling value adding collaboration	Effective project, change and risk management tools and procedures in place including offshore wind specific management systems, comparable to the oil and gas sector. All developers plan a framework enabling value adding collaboration	Effective project, change and risk management tools and procedures in place including offshore wind specific management systems, comparable to the oil and gas sector. All developers plan a framework enabling value adding collaboration

		contemporary approaches such as BIM.	with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.	with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.	with all project partners at an early stage. Standardised approaches like BIM starting to be used on commercial projects.
On target	50% of developers have specific offshore management system with effective risk and change management systems	Majority of developers have specific offshore management system with effective risk and change management systems. They plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.	All major developers have specific offshore management system with effective risk and change management systems. They plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.	Effective project, change and risk management tools and procedures in place including offshore wind specific management systems, comparable to the oil and gas sector. All developers plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.	Effective project, change and risk management tools and procedures in place including offshore wind specific management systems, comparable to the oil and gas sector. All developers plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.
Behind target	Quarter have specific offshore management	Quarter of developers have specific offshore	Some developers have specific offshore	50% of developers have specific offshore	Majority of developers have specific offshore

	system with effective risk and change management systems	management system with effective risk and change management systems	management system with effective risk and change management systems	management system with effective risk and change management systems. They plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from contemporary approaches such as BIM	management system with effective risk and change management systems. They plan a framework enabling value adding collaboration with all project partners at an early stage, taking some influence from contemporary approaches such as BIM.
Missed target	No improvements	One or two developers have offshore wind specific management systems in place with emerging risk and change management approaches	Quarter have specific offshore management system with effective risk and change management systems	Some developers have specific offshore management system with effective risk and change management systems	50% of developers have specific offshore management system with effective risk and change management systems

5.3 Evidence

5.3.1 Questionnaires

Category	Questionnaire response
Describe the management systems you use in the development phase of projects. In particular describe your approach to risk and change management, what tools are available and whether these have been developed specifically for offshore wind.	
Designer / Survey	We are looking to incorporate some of our services into these management systems but we don't currently have a fully developed system ourselves.
[Developer]	During the development phase of the project we use the same project management system as in the later more involved stages, but to some extent scaled down appropriate to the smaller team and lower value of the project at that stage. The [Developer] project management system was originally based on the PMBoK but has since been adapted largely in house to reflect the characteristics of our offshore wind projects (few projects running for long periods as opposed to many shorter projects) and the needs of our partners. The system includes all the normal project managements elements including scope definition, definition of roles and organisation structure, stakeholder management, risk management, quality management, cost control, change management, monitoring, reporting audit and lessons learned capture and implementation. We use full quantitative risk analysis @Risk to develop project contingency by the end of the development phase. Change control is phased in once sufficient baseline thresholds have been established such as the issue of employers requirements and design freeze stage gates.
[Developer]	Development phase management system alongside wider project management systems have gradually been modified or replaced for the offshore wind area of the business. Examples include management systems for H&S, Environmental, Quality Management and Document Control, Risk Management, Interface Management and Change Management.

	Policies, Processes and Execution Plans have also been developed for each project. Most management tools are bespoke, developed in-house utilizing existing IT systems or based on excel spreadsheets
Describe any major improvements to this management system that have been implemented over the past three years.	
Designer / Survey	We are looking at more accurate weather forecasting models
[Developer]	Over the last three years the system has been optimised to be streamlined and more user friendly, encouraging its adoption by all personnel. In particular the quantitative risk analysis has been refined through testing the methodology with financial stakeholders through acquisitions and non-recourse project financing. This has also resulted in detailed contingency planning which has been of benefit to projects. In the most recent projects we have been working more collaboratively with multiple parties including co-investors and contractors using shared information platforms and as such the development of more comprehensive document and information management process has also been prioritised
[Developer]	It has been a gradual evolution, made more challenging by the requirement to work in very different project frameworks, with different JV partners and also having to respect wider company standards and tools
Do you have a specific offshore wind development phase management system?	
Designer / Survey	No
[Developer]	No

[Developer]	Yes
Do you feel that management systems are effective, and do you see any potential for improvements in the near future?	
Designer / Survey	We think we can help to improve them with better weather forecasting models
[Developer]	The management system is effective but it can certainly be improved. For instance some aspects of the peer reviews carried out have been difficult to manage effectively.
[Developer]	There is scope for further improvement of management systems and more standardized systems across the industry. One specific area we are currently looking to improve is interfaces by introducing a more powerful interface management tool, web-based with a simple user-interface
Finally, have you considered more structured collaborative ways of work such as BIM (Building Information Modelling)?	
Designer / Survey	We are involved with BIM in other business, we offer electronic data management and data transfer which can be incorporated into BIM software.
[Developer]	We have not yet implemented BIM formally although some principles of it are in use including collaborative digital online data models, 3-D models, and collaborative design spaces.

[Developer]	We are collaborating using 3D models in design and construction. We have not yet taken this as far as implementing a BIM tool.

5.3.2 Interview

Category	Interview response
None for this indicator	

5.3.3 Market intelligence

Evidence	Source
None for this indicator	

5.4 Additional comments

None for this indicator

5.5 Recommendations

None for this indicator

6 Floating Lidar

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Project management and development	Project management and development	Floating Lidar

6.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ for 2016 because a significant portion of the 2020 target for this indicator has been achieved already. Several floating lidar systems have been deployed on demonstration and fully commercial projects. Offshore wind projects have successfully achieved FID based solely on wind data from floating lidar systems, and it is expected that this trend will continue to offer reduced cost wind resource assessments in future on other projects.

Last year this indicator was also easily assessed as being ‘ahead of target’ noting specific project uses and progress beyond demonstration phase evidenced by commercial application.

This indicator is an example of progress in technology development and adoption that has significantly exceeded the pace anticipated by either CRP in 2012 or CRMF 2014. As such it is likely that several projects currently in development and construction are already experiencing cost savings associated with the use of floating lidar, and that more will do so as the technology continues to improve.

Outlook:

The outlook for this indicator is positive. Future potential impacts on continued progress could come from consolidation of active suppliers. Additionally there has been limited evidence to date of the application of floating lidar to the operational phase of projects, however it is anticipated that the majority of cost reduction potential offered by floating lidar is in the development phase, and as such if widespread adoption in the operational phase as predicted by CRMF 2014 does not materialise it is not expected to significantly deteriorate the cost reduction potential.

A ‘high confidence’ was expressed by the industry in the outlook for this indicator. There is almost universal consensus that floating lidar will continue to form the backbone of future offshore resource assessments, with clear ongoing benefits to the development cost of projects.

6.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Second floating lidar unit deployed.	First use of floating lidar on operational projects	Floating lidar units are proven and used to offset the use of met masts on a small number of sites, and being used in the operations phase.	Floating lidar units are proven and used to offset the use of met masts on a small number of sites, and being used in the operations phase.	Floating lidar units are proven and used to offset the use of met masts on a large number of sites, and being used in the operations phase.

On target	First floating lidar unit deployed on a wind farm	Floating lidar units are proven. Second floating lidar unit deployed	First use of floating lidar on operational projects	Floating lidar units are proven and used to offset the use of met masts on a small number of sites, and being used in the operations phase.	Floating lidar units are proven and used to offset the use of met masts on a small number of sites, and regularly being used in the operations phase.
Behind target	Successful testing and verification of floating lidar units	First floating lidar unit deployed on a wind farm	Floating lidar units are proven. Second floating lidar unit deployed	First use of floating lidar on operational projects	Floating lidar units are proven and used to offset the use of met masts on a small number of sites, and being used in the operations phase.
Missed target	Trials unsuccessful with no further development	Trials unsuccessful with no further development	Trials unsuccessful with no further development	Trials unsuccessful with no further development	Trials unsuccessful with no further development

6.3 Evidence

6.3.1 Questionnaires

Category	Questionnaire response
Are you using floating lidar on your projects?	

Designer / Survey	Yes
[Developer]	No
If so, what for?	
Designer / Survey	[COMPANY] has developed a floating LiDAR buoy which our clients are using to assess wind resource. We can also measure other metocean parameters at the same time.
[Developer]	Have trialled these at [PROJECT] offshore wind project . Currently no UK sites that we are developing require this technology. We will keep a watching brief on this technology
Please detail any offshore wind projects you are aware of that are utilising floating lidar and detail the applications e.g. wind resource assessment, power performance assessment, O&M planning.	
[Lidar]	Please ask the floating lidar providers this question. Whereas I am aware of many of them it is by no means exhaustive and I have to assume everything is commercial in confidence whereas they may be able to open up a little more. I am very confident that we will see increasing use of floating lidars in the development phases of offshore wind farms and by 2020 should be regularly replacing the use of offshore met masts. The use of floating lidars in the operational phase of the wind farm is less certain. Nacelle mounted forward facing lidars offer an exceptionally good view of the turbine's performance, and there is increased use of fixed lidars on offshore wind farm structures; transformer platforms. The only way that I see this potentially having a higher adoption would be if the operators started to look at IEC61400-12-1 Ed 2 power curves and a floating mast/lidar hybrid became an acceptable

	compliant power curve measurement. There is a new generation of floating mast platforms but it remains to be seen as to how well the traditional mast anemometry performs even with slight motion effects. I have tried to reflect this in the score of 3 below.
[Lidar]	All projects that I am aware of are using floating lidar as a wind resource assessment tool.
[Lidar]	No involvement.
Have you used floating lidar in the operations phase of projects, or do you have any plans to do so in the next year? e.g. for power performance assessment, weather (wind and wave) measurements for logistics planning etc.	
Designer / Survey	Not yet but we are interested to do so.
[Developer]	technology has been used as part of an R&D trial during the construction phase of the project. No plans yet to use for operations phase.
If so, what for?	
Designer / Survey	N/A
[Developer]	See above

6.3.2 Interview

Category	Interview response
[Developer]	Development of [PROJECT] site was unique as were able to obtain very nearby met data from another met mast so did not need to investigate floating lidar, which was a cost reduction but was really a one off experience. On [PROJECT] [Developer] had an onshore lidar on IoW and a floating lidar which came from a [LOCATION] [COMPANY] site previously to [PROJECT]. Whilst acknowledging that this was some years ago, there were some significant operational issues with the floating lidar and it was not a trouble free technology. Agree that in time floating lidar will become more popular for wind resource investigations and is highly likely to displace offshore met masts. For example [Developer] are using one on a [LOCATION] site now. So although there have been operational challenges these are not a show stopper for floating lidar, it will mature and will continue to be relied upon. Putting together soil investigation and wind campaign, there is a trend that they have seen and are following; there is comfort in following innovation on wind campaign that can help to avoid expensive met masts in the water, soil investigation is where money has to be spent before FID. There has been innovation in wind assessment that has allowed an easing of the pre FID budget, and moving some of that budget across to survey and soil investigation has been done by developers to better balance the requirements of a project for data, and the requirement to keep pre FID costs in check.

6.3.3 Market intelligence

Evidence	Source
• On 03/12/2015 Fraunhofer wind technology research group announced development of lidar-based wind monitor to optimize turbine performance.	http://optics.org/news/6/12/6
• On 12/01/16 ECN announced that the Fugro Oceanor Seawatch floating LiDAR is in the pre-commercial stage according to the Offshore Wind Accelerator (OWA) roadmap for the commercial acceptance of floating LiDAR technology. In collaboration with RWE, Eneco and Fugro Oceanor ECN has performed a Fugro Oceanor Seawatch floating LiDAR validation trial near the offshore meteorological mast IJmuiden, located in North sea about 75km from the Dutch shore.	https://www.ecn.nl/news/item/floating-lidar-technology-cost-effective-solution-for-offshore-wind-farm-development/
• On 18/01/16 Fugro installed a floating LiDAR device on ScottishPower Renewables' East Anglia One (EA1) wind farm zone as part of the Carbon Trust's Offshore Wind Accelerator (OWA) programme for a 6-month trials.	http://www.4coffshore.com/windfarms/floating-lidar-deployed-at-east-anglia-one--nid3157.html
• On 10/02/16 ECN reported that EOLOS FLS200 floating LiDAR performs in compliance with the KPIs (Key Performance Indicators) of the Carbon Trust’s roadmap for the commercial acceptance of floating LiDAR	http://www.offshorewind.biz/2016/02/10/eolos-fls200-floating-lidar-

technology. In October 2015, the EOLOS FLS200 floating LiDAR buoy completed a 6-month validation campaign next to the IEC-compliant IJmuiden offshore meteorological mast in the North Sea.	validated-for-offshore-wind-measurements/
• In February 2016, AXYS Technologies announced that recently completed another two successful validation campaigns for its FLiDAR 6M wind-assessment platform which took place at FINO 1 in the North Sea and at West of Duddon Sands in the Irish Sea.	http://www.windpowerengineering.com/featured/business-news-projects/axys-leads-the-way-to-commercial-acceptance-of-floating-lidar/
• On 31/05/16 Carbon Trust announced that as part of the Offshore Wind Accelerator (OWA), trials in Dublin Bay that are due to be completed shortly will be the most comprehensive test of scanning lidar technology ever undertaken and will see four different scanning lidar systems put through their paces alongside three vertical profiling lidars for validation purposes. The units involved in the trial were: three Leosphere WINDCUBE vertical profiling lidars, a Leosphere WINDCUBE 400S scanning lidar, a Leosphere prototype scanning lidar and two Lockheed Martin WindTracer scanning lidars.	http://www.owjonline.com/news/view,trials-see-carbon-trust-creating-3d-lidar-wind-maps_43130.htm
• On 01/06/16 the floating lidar of the BLIDAR project began a 6-month validation campaign in the Mediterranean Sea concluding an R&D program associating two SMEs, Eolfi and nke Instrumentation, as well as two research institutes, the Institut Carnot Ifremer-Edrome, and IRSEEM.	http://www.nke-instrumentation.com/news/detail-

	actualite/article/the-floating-lidar-of-the-blidar-project-begins-a-6-month-validation-campaign-in-the-mediterranean-s.html
• On 02/06/2016 Nass&Wind Smart Services(link is external) installed its Wind LiDAR Buoy, the M3EA platform, off the coast of Dunkirk in France. The system is collecting wind data to achieve the set objectives, wind resource assessment and characterization for the future offshore wind farm.	http://www.offshorewindindustry.com/news/wind-measurement-campaign-m3ea-wind-lidar
• On 12/09/16 Ecofys WTTS carried out an uncertainty assessment of the Fugro Oceanor AS Seawatch wind lidar buoy to support the Netherlands Enterprise Agency in driving down uncertainties and costs for developers for the next round of Dutch offshore tenders. The aim of the study was to quantify the certainty with which the wind data, currently measured at the offshore wind farm zones Hollandse Kust and Borssele, can be used in calculation of final wind resource assessments, Ecofys WTTS said.	http://renews.biz/104114/germans-test-dutch-lidar-strength/

6.4 Additional comments

None for this indicator

6.5 Recommendations

None for this indicator

7 Turbine rating

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Nacelle	Turbine rating

7.1 Summary Analysis

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

Finding: Ahead of target

Marked as ahead of target in 2016 because there is no evidence of UK offshore projects planning to use turbines other than in the 5 – 7 MW class or larger. This year has seen commercial deployment of the MHI Vestas V164 8 MW at the Burbo Bank Extension wind farm. Subsequently an increase in output was announced by MHI Vestas to 8.3 MW for the near future Blyth Offshore wind farm project using the same turbine platform. Siemens have recently installed 6MW turbines in the UK, will install 7 MW in the near future on UK projects including Beatrice and East Anglia One, and have since announced plans for European deployments of the same platform with a rating up to 8.4 MW.

Last year this indicator was also scored as ‘ahead of target’ because 6+ MW turbine platforms were already dominating the market.

Outlook:

The outlook for this indicator remains positive, as the requirement for at least 40% of projects contracting 7-9MW class turbines by 2020 already looks highly likely to be achieved. Whether an increase in rating to 9+ MW class machines will come from either gradual upgrading of existing 6 – 8 MW platforms or whether one or more turbine OEM will release an entirely new turbine platform remains to be seen. However, based on the history of upgrades to previous turbine platforms it does look likely that through extending capabilities of currently available platforms a 9+ MW turbine will comfortably be available on the market by 2020. The release of a subsequent generation of turbine platform beyond 10 MW is possible but unlikely before 2020.

A 'high confidence' was expressed by the industry in the future outlook for this indicator. The significant cost reduction contributed by increasing turbine ratings has probably delivered earlier than may have been expected, but nevertheless there remains a confidence in continuing gradual improvements in rating, even if a significant further step change remains unlikely ahead of 2020.

7.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	5-7 MW Class Turbines dominate, some 7-9 MW contracted	No turbines below 5-7 MW. 7-9 MW class reaches 20%. 9 MW + being tested	A third of projects reaching FID use 7-9 MW	Half of projects contract 7-9MW class turbines in 2020. 9 MW+ turbines available on market	A half of projects contract 7-9 MW class turbines in 2020. 9 MW+ turbines available on market
On target	5-7 MW Class in majority. 7-9 MW available to market	5-7 MW Class Turbines dominate. First project contracts using 7-9 MW turbines	No 3-5MW turbines being installed, with 2/3rds 5-7 MW. 1/3rd of projects use 7-9 MW. 9 MW +	A third of projects reaching FID use 7-9 MW. 9 MW+ turbines on the market	Half of projects contract 7-9 MW class turbines in 2020. 9 MW+ turbines available on market

			being tested offshore		
Behind target	Even split between 3-5 MW and 5-7 MW turbines. 7-9 MW being demonstrated	5-7 MW Class in majority. 7-9 MW available to market	5-7 MW Class Turbines dominate, some 7-9 MW contracted	No turbines below 5-7 MW. 7-9 MW class reaches 20%. 9 MW + being tested	A third of projects reaching FID use 7-9 MW
Missed target	No testing of 7-9 MW turbines underway. No	Even split between 3-5 MW and 5-7 MW turbines. 7-9 MW being demonstrated	5-7 MW Class in majority. 7-9 MW available to market	5-7 MW Class Turbines dominate, some 7-9 MW contracted	No turbines below 5-7 MW. 7-9 MW class reaches 20%. 9MW + being tested

7.3 Evidence

7.3.1 Questionnaires

Category	Questionnaire response
What orders for offshore wind turbines do you think you will sign this year in Europe and for which of your turbine products? Provide details of projects and any framework agreements that you have signed.	
[WTG OEM]	[PROJECT] - 32 x [PRODCT] WTGs with power upgrade (6.33 MW capacity each)
[WTG OEM]	2 [WTG OEM] [PRODUCT] turbines for the [PROJECT] at [LOCATION]
[WTG OEM]	After concluding a number of projects in 2016, no UK orders expected in 2017 as a result of delayed auction process

[WTG OEM]	Confidentiality considerations
What rating (in MW) of turbine do you expect to commit to using on your next project and any other projects before 2020?	
[Foundation]	No input
[Developer]	6 MW to 10 MW

7.3.2 Interview

Category	Interview response
What orders for offshore wind turbines do you think you will sign this year in Europe and for which of your turbine products? Provide details of projects and any framework agreements that you have signed.	
[WTG OEM]	Everybody has reached FID on Fider projects recently, so 2016 has been a great year as there have been lots of projects reaching FID and now have a strong pipeline of projects for the near future. There are no expectations of any project being able to take FID in 2017 as there has been no auction for some time. It is clear to see that this will result in a trough in orders once projects which do have support are completed. [WTG OEM] are recruiting 1000 people for their new factory in [LOCATION]. They have good order book to justify that up to ~2021, but need to understand what the pipeline could be thereafter, there is likely to be a gap once the first auction round

	project(s) are completed. Risk that may not be able to have such a volume of staff/work as there has been a ~2 year delay in auctions for support.
[WTG OEM]	The [COMPANY] offering has already been upgraded to 6.33 MW 152 m rotor diameter, more details in questionnaire response.
What rating (in MW) of turbine do you expect to commit to using on your next project and any other projects before 2020?	
[WTG OEM]	In terms of turbine rating more specifically [WTG OEM] have got 8 projects to build now, a few (the earliest) will be 6 MW, but most will be 7 MW or 8 MW versions of the same platform. Unlikely to have a next generation turbine ready to install until well into 2020s. Do not expect a new generation or turbine platform soon, although they are starting to work on it/consider it, very unlikely until mid-2020s. Looking back, it was pretty easy to make the decision to develop 6MW platform based on anticipated size of market at the time that this project was initiated. When considering what future platform may come next, consider that very roughly speaking the R&D cost would be [significant] to develop a new platform, it is not a decision that can be taken lightly or without some confidence that there will be a sufficient market to sell sufficient number of these products into. Indeed taking a world view and potential pipeline in say, USA could be something that justifies such an investment if it grows rapidly and new markets contribute to a sufficiently visible pipeline. At the moment it looks to be some distance from there being sufficient potential market to attract [WTG OEM] (or other OEMs) into delivering another new platform.

[Developer]	The next project they expect to be working on will be French ones which will still be in the 6 – 8 MW generation of turbines. [Developer], like most are doing work internally to develop views on 2020 and beyond, there is not a single view, but there could be an improvement from current generation to consolidate on 8 – 9 MW version of current turbines, OR there could still be a step change to a new turbine platform which is notably larger. It is not certain yet which of these two potential routes will be followed by either a single turbine OEM or by the industry. Consents exist for a lot of projects already, and a step change in turbine platform would be a headache for consenting and civils on many sites. Constrains may not come from turbine OEM, for example it could be consenting and BoP that means a 10+ MW turbine is pushing the limits of what is achievable, even for sites that are in development.

7.3.3 Market intelligence

Evidence	Source
• According to 4c Offshore, in Europe 20 projects reached financial close since October 2015. 17 have already decided a model of turbine with only five of them (30%) planning orders of <7 MW turbines (Merkur, Arkona, Tahkoluoto Offshore Wind Power Project, Galloper Wind farm, Hywind Scotland Pilot Park windfarms). 35% of projects were in the 7 MW class and the rest 35% in 8 MW. The demand for larger MW turbines in terms of power output is constantly increasing. (4C Offshore)	4C Offshore
• On 28/10/15 Siemens announced that received first offshore order for the new 7 MW offshore wind turbine: the company is to supply, install and commission 47 direct drive wind turbines, each with a rotor diameter of 154	http://www.siemens.com/press/en/pressrelease/2015/w

meters. The wind turbines will be deployed in the Walney Extension East project in the Irish Sea. The developer and owner of the offshore wind power plant is DONG Energy.	indpower-renewables/pr2015100057wpen.htm?content[]=WP
• In July 2016, German manufacturer Siemens has unveiled its new 8 MW offshore wind turbine, the SWT-8.0-154, which it hopes will play a significant role in achieving grid parity for offshore wind. Siemens says that the first SWT-8.0-154 will be installed in early 2017, and is expected to provide up to 10% higher annual energy production under offshore wind conditions, as compared to its 7 MW model. The new 8 MW turbine is making use of new magnet technology which enables a rated power increase of more than 14% over its 7 MW predecessor.	https://cleantechnica.com/2016/07/06/siemens-unveils-new-8-mw-offshore-wind-turbine/
• On 07/09/16 the wind power unit of Japanese diversified group Hitachi Ltd (TYO:6501) expects to release a new 5 MW offshore turbine in fiscal year 2017, subject to successfully concluding a trial run. The company said today it has developed the HTW5.2-136, an offshore wind turbine with a downwind configuration, rated power of 5.2 MW and a 15% larger rotor swept area thanks to an increase of the rotor diameter to 136 metres (446.2 ft). Hitachi Wind Power intends to market the machine for use in light-wind regions along the coasts of Honshu, the main island of Japan, it noted.	http://renewables.seenews.com/news/hitachi-expects-to-release-new-5-mw-offshore-wind-turbine-in-fy-2017-538951
• WPD has applied to build the 865 MW Gennaker offshore wind farm in the German Baltic Sea. The plans include 103 Siemens SWT-8.0-154 turbines optimized to 8.4 MW.	http://renews.biz/104189/wpd-lays-baltic-bet/

The V164-8.0 MW turbines – rated with a capacity of 8 MW – have been optimised for the Blyth Offshore project, utilising a power mode to be able to deliver a maximum output of 8.3 MW, further increasing the value for the customer.	http://www.mhivestasoffshore.com/mhi-vestas-offshore-wind-receives-41-5-mw-order-blyth-wind-farm-uk/
The first V164-8.0 MW wind turbine has been installed at DONG Energy's 258 MW Burbo Bank Extension project off the coast of Liverpool, UK. The turbine is the first of 32 to be installed at the site, which will set a new benchmark as the first offshore project to utilise the world's most powerful wind turbine.	http://www.mhivestasoffshore.com/first-v164-8-0-mw-turbine-installed-burbo-bank-extension-2/

7.4 Market share by turbine rating

Turbine model	Platform rating (MW)	EU FID 2016 Capacity (MW)	% of EU FID 2016 MW	Number of turbines	% of EU FID 2016 Turbines
Siemens SWT 4.0-130	4.00	40.00	0.79	10.00	1.41
Subtotal (3MW - 5MW)			**0.79**		**1.41**

Haliade 150	6.00	396.00	7.86	66.00	9.34
Siemens SWT 6.0-154	6.00	385.00	7.64	60.00	8.49
Subtotal (5MW - 7MW)			**15.50**		**17.82**
Siemens SWT 7.0-154	7.00	2857.00	56.71	406.00	57.43
MHI Vestas V164 8.0	8.0	1360.20	27.00	165.00	23.34
Subtotal (7MW – 9MW)			**83.70**		**80.76**

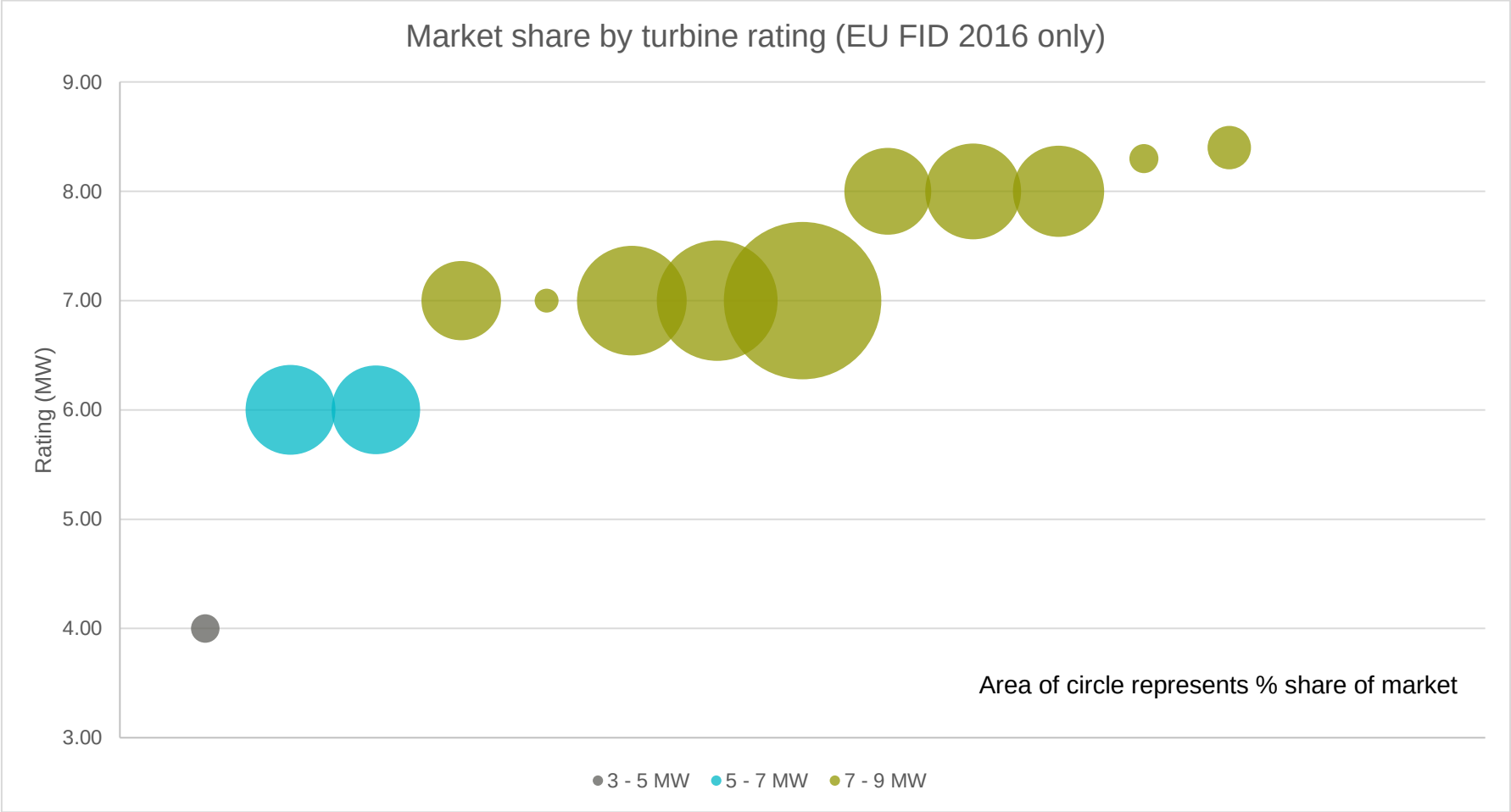

Figure 1 - Market share by turbine rating (EU FID 2016 only)

7.5 Additional comments

None for this indicator

7.6 Recommendations

None for this indicator

8 Turbine drive train concept

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Nacelle	Turbine drive train concept

8.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	On target	↓	Medium confidence

Finding: On target

Marked as on target in 2016 because projects are reaching FID and works completion with a balanced mixture of medium speed and direct drive layouts, and there has been a steady evolution of drive train technologies in the industry leading up to the variety of drive train layouts currently available. There has been some evidence of early prototype testing of innovations in turbine drive train at small scale, but there is no evidence of the introduction of variable speed drivetrains to the market or any significant work underway to advance superconducting generator development, which has been key in moving this indicator downwards from the 'ahead of target' assessment last year.

In 2015 this indicator was marked ahead of target because direct drive and medium speed drive trains were evident in roughly equal numbers. It is possible that this indicator could fall further behind to 'behind target' next year, although that would not necessarily indicate a failure to deliver cost reduction, rather that the significant reductions were achieved much earlier than was predicted.

There continues to be a trajectory towards a variety of drivetrain concepts on the market, although the trend of turbine OEM consolidation which was highlighted last year as being responsible for the removal of radical concepts (such as the MHI Sea Angel) is continuing, and it now looks unlikely that any drive train concepts other than medium speed gearboxes or direct drive will receive the support of a major turbine OEM before 2020.

Outlook:

Due to the current relative stability in the small number of commercially available turbine platforms it is unlikely that significant further step changes in turbine drive train concept will be available to the offshore market before 2020. Progress in this area in future may also be affected by the ongoing consolidation of major turbine OEMs.

A ‘medium confidence’ in the future outlook for this indicator was expressed by the industry, reflecting the view that it appears relatively unlikely that the predominant trend, and mix of direct drive and medium speed drivetrain layouts will change significantly by 2020, there is limited expectation of development or demonstration of any new drivetrain technologies.

8.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Range of drive train solutions available to the market. Introduction of variable speed drive train	Mid-speed gearbox designs in majority, still substantial direct-drive turbines	Mid-speed gearbox designs in majority, still substantial direct-drive turbines	Turbine market dominated by direct-drive and mid-speed generator solutions, with first trials of superconducting and variable speed direct-drive drive trains, new drivetrains being brought to market	Optimum drive train for 5-9 MW turbines clearly established.

				following improvements in workshop verification testing.	
On target	Mid-speed gearbox designs and direct-drive turbines roughly equal in numbers. Testing of super-conducting and variable speed direct drive gearboxes begins on test rigs	Range of drive train solutions available to the market. Introduction of variable speed drive train	Mid-speed gearbox designs in majority, still substantial direct-drive turbines	Mid-speed gearbox designs in majority, still substantial direct-drive turbines	Turbine market dominated by direct-drive and mid-speed generator solutions, with first trials of superconducting and variable speed direct-drive drive trains, new drivetrains being brought to market following improvements in workshop verification testing.
Behind target	Increasing use of mid-speed gearboxes for more recent (larger) turbine designs	Mid-speed gearbox designs and direct-drive turbines roughly equal in numbers	Range of drive train solutions available to the market. Introduction of variable speed drive train	Mid-speed gearbox designs in majority, still substantial direct-drive turbines	Mid-speed gearbox designs in majority, still substantial direct-drive turbines
Missed target	First concepts only entering the market now	Increasing use of mid-speed gearboxes for more recent (larger) turbine designs	Mid-speed gearbox designs and direct-drive turbines roughly equal in numbers	Mid-speed gearbox designs and direct-drive turbines roughly equal in numbers	Range of drive train solutions available to the market. Introduction of continuously variable

					transmission drive train for 8 MW turbine

8.3 Evidence

8.3.1 Questionnaires

Category	Questionnaire response
Describe your current turbine offering to the market in terms of MW size, rotor diameter, drive train concept, tip speed, design life and operational experience.	
[WTG OEM]	[PRODUCT] Power Upgrade - Turbine rated at 6.33 MW, 152m rotor diameter, high-speed geared machine featuring a DFIG system, max tip speed is around 80 m/s, design life of 25 years. Design based on well-proven [PRODUCT] and [PRODUCT] turbines, of which there will be 1.3 GW installed offshore by the end of 2017
[WTG OEM]	Delivering 6 MW turbines on projects today. 7 MW and 8 MW variants available on future projects through generator upgrades to same platform. 25 year life, 154 m rotor Direct Drive
[WTG OEM]	[PRODUCT]: 5 MW; 132 m. rotor diameter; permanent magnet generator (PMG), gearbox; 20 years, design life; one operating offshore prototype and 32 units onshore model operating. [PRODUCT]: 5 MW; 135 m. rotor diameter; PMG and gearbox; 25 years. Design life time; 132 units of predecessor model. [PRODUCT]: 8 MW; 180 m. rotor diameter.

What drivetrain layout (e.g. high speed, medium speed, or direct drive are you planning to use on your next project and any other projects before 2020?	
[Developer]	Medium speed and Direct Drive in operation at UK sites
Are you aware of any demonstration or trials of radical drivetrain technologies such as superconducting generators or variable speed? If so, please detail.	
[WTG OEM]	No
[WTG OEM]	No
[WTG OEM]	Not currently
[WTG OEM]	Research papers have been published in Asia and Europe. [WTG OEM] has reported two prototypes with superconductors operating at 3 MW. [COMPANY] is also reported to have trials on demonstration.
[Developer]	Eco Swing project Super conductor Generator. Digital Hydraulic Power System

8.3.2 Interview

Category	Questionnaire response
None for this indicator	

8.3.3 Market intelligence

Evidence	Source
• On 21/06/16 ENGINEERS AT NREL have completed tests on an unusual wind-turbine drivetrain design which sports a single-stage gearbox designed by Romax Technology, a medium-speed PMG, and a power converter developed by DNV Kema with high-efficiency modules developed by Cree (now Wolfspeed). The goal of the project's first phase, which began in 2011, was to design an advanced drivetrain that could improve reliability and efficiency, reduce the cost of wind energy, and scale to larger power ratings.	http://www.windpowerengineering.com/featured/nrel-readies-new-wind-turbine-drivetrain-commercialization/
• On 02/09/16 in close cooperation Adwen and Winergy developed the gearbox for Adwen's AD 8-180 offshore wind turbine. With an input torque of close to 10,000 kNm and a weight of 86 tonnes it is the largest wind turbine gearbox ever built in the world.	http://www.offshorewindindustry.com/news/worlds-biggest-wind-turbine-gearbox

• GreenSpur renewables have described a project with focus to model the use of cheaper ferrite (iron-based) magnets, and to determine from first principles if it would be possible to design a new topology that could deliver a competitive direct-drive PMG.	http://www.windpowermonthly.com/article/1396547/windtech-concepts-eliminate-reduce-pmg-use

8.4 Market share by drivetrain layout

Turbine model	Drivetrain layout	EU FID 2016 Capacity (MW)	% of EU FID 2016 MW	Number of turbines	% of EU FID 2016 Turbines
Siemens SWT 4.0-130	High speed	40.00	0.79	10.00	1.41
Subtotal (High speed)			**0.79**		**1.41**
MHI Vestas V164 8.0	Medium speed	1360.20	27.00	165.00	23.34
Subtotal (Medium speed)			**27.00**		**23.34**
Haliade 150	Direct drive	396.00	7.86	66.00	9.34

Siemens SWT 6.0-154	Direct drive	385.00	7.64	60.00	8.49
Siemens SWT 7.0-154	Direct drive	2857.00	56.71	406.00	57.43
Subtotal (Direct drive)			**72.21**		**75.25**

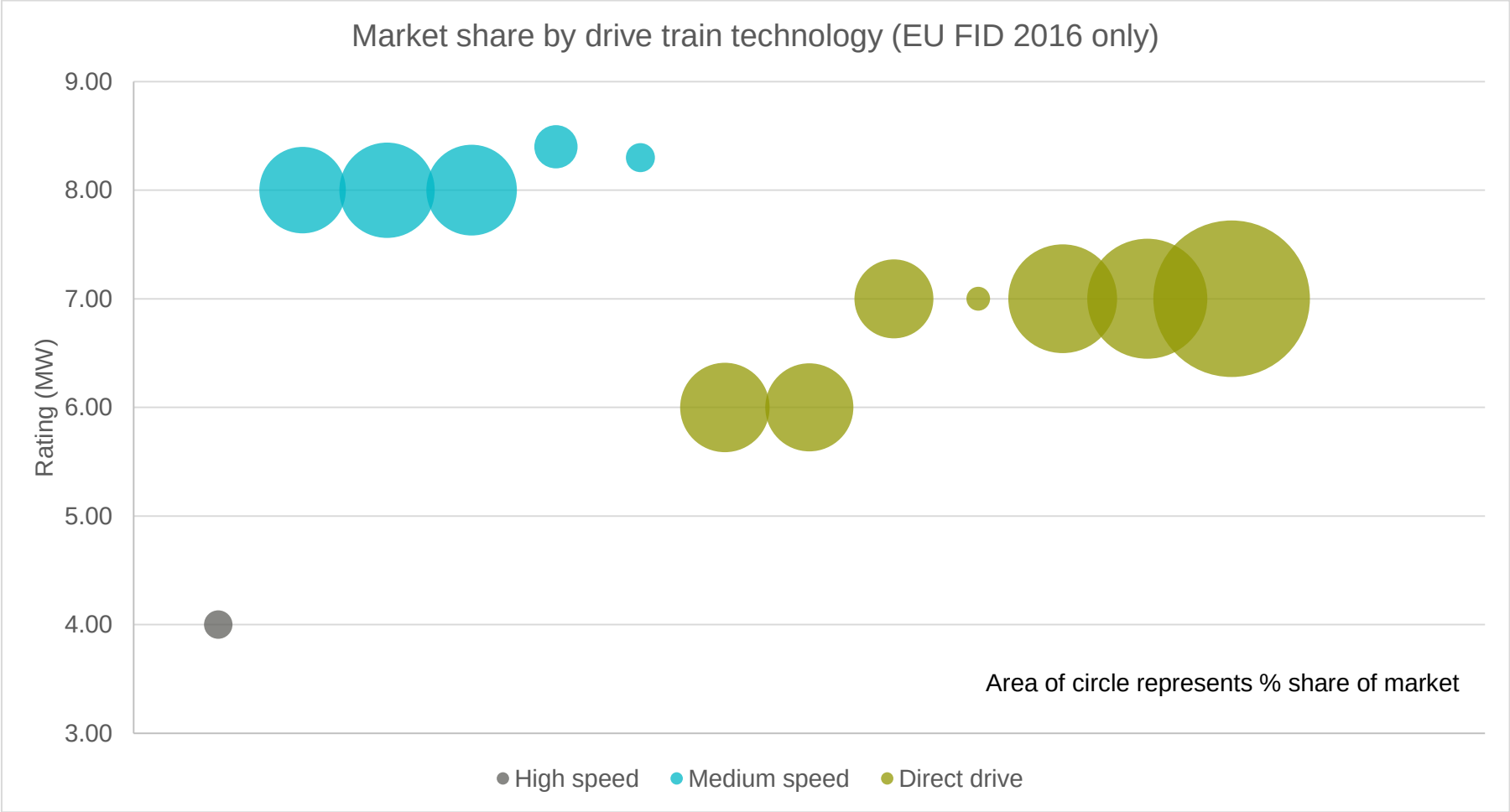

Figure 2- Market share by drive train technology (EU FID 2016 only)

8.5 Additional comments

None for this indicator

8.6 Recommendations

None for this indicator

9 Turbine AC power take off design

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Nacelle	Turbine AC power take off design

9.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016 despite limited direct evidence provided by turbine OEMs or their suppliers. It is suggested that there are continued incremental evolutionary improvements in power electronic equipment. There is evidence suggesting that improvements in software and control strategies for power electronics have offered technology advancement. Additionally turbine OEMs continue to announce uprated versions of their turbine platforms, and it is understood that a proportion of the increased capacity available has often been delivered as a result of AC power take off system improvement.

Last year this indicator was also scored as ‘on target’ based mainly on evidence of continued incremental improvement and a lack of any evidence suggesting radical new architectures which continues to be the case this year.

Power electronics are still commonly cited as causes of significant cost impacts in the operational phase of projects. However, the AC power take off systems used in the current and future generation of offshore WTG have currently a limited track record, and as such it is difficult to have certainty in what level of improvement may be provided by the current 6-8 MW turbine platforms over those used in a previous 3-4 MW generation of WTG as the length of operational experience is still low.

Outlook:

Having certainty in the future outlook for this indicator from an independent viewpoint is challenging as a result of the commercial sensitivity of information relating to the design, development and deployment of these systems. There has been a reluctance to share information to inform this study which may represent to some a competitive advantage. It is clear that there is space for continued improvement in reliability of these systems, with remaining potential in the development and optimisation of control strategies highlighted as an opportunity alongside the new architectures and materials forecast by the future milestones for this indicator.

A ‘medium confidence’ was expressed by the industry in the outlook for this indicator, which is reflective of the remaining potential for further development in this area.

9.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	New converter architectures may take significant market share. Continued improvement in power-electronic device efficiency, size and cost.	New converter architectures may take significant market share. Continued improvement in power-electronic device efficiency, size and cost.	Almost all projects with 6 MW+ turbines use better power take off technology	Almost all turbines installed used advanced converter architectures and devices, with substantial improvements in efficiency, size and cost.	Almost all turbines installed used advanced converter architectures and devices, with substantial improvements in efficiency, size and cost.

On target	Power-electronic device improvements in efficiency, size and cost. No significant new converter architecture.	A third of projects with 6 MW class turbines and larger use improved technology. New converter architectures appear on commercial turbines	A third of new turbines have new converter architectures. Continued improvement in power-electronic device efficiency, size and cost.	New converter architectures may take significant market share. Continued improvement in power-electronic device efficiency, size and cost.	Almost all projects with 6 MW+ turbines use more efficient, smaller and faster-switching power conditioning electronics, with greater reliability and self-health-monitoring, made from new materials
Behind target	Power-electronic device improvements in efficiency, size and cost. No new converter architecture.	Power-electronic device improvements in efficiency, size and cost. No significant new converter architecture.	Half of projects with 6 MW class turbines and larger use improved technology. New converter architectures appear on commercial turbines	New converter architectures may take significant market share. Continued improvement in power-electronic device efficiency, size and cost.	New converter architectures may take significant market share. Continued improvement in power-electronic device efficiency, size and cost.
Missed target	no improvements	Power-electronic device improvements in efficiency, size and cost. No new converter architecture.	Power-electronic device improvements in efficiency, size and cost. No significant new converter architecture.	Half of projects with 6 MW class turbines and larger use improved technology. New converter architectures appear on commercial turbines	50% of projects with 6 MW class turbines and larger use improved technology. New converter architectures appear on commercial turbines

9.3 Evidence

9.3.1 Questionnaires

Category	Questionnaire response
Are you seeing any improvement in your power take off design in terms of efficiency, size and cost? Provide examples where possible.	
[WTG OEM]	Yes. All offshore turbines are increasing their power output by approx. 5% to comply with type certificate requirements. In [WTG OEM]'s case, this increases the power output to 6.33 MW for the [PRODUCT]
[WTG OEM]	New generator systems fully programmable, offering grid services such as synthetic inertia
[WTG OEM]	[PRODUCT] will achieve Type Certificate and be in serial manufacturing in 2018, taking "mainstream" turbine models to new 7-8 MW nominal capacity range. [PRODUCT] platform designed for scalability.
Are you aware of turbine OEMs offering improved power converter systems on new turbine products (e.g. condition monitoring or new materials for power converters)? If so please provide details.	
[WTG OEM]	Yes

[WTG OEM]	New generator systems fully programmable, offering grid services such as synthetic inertia
[WTG OEM]	Confidentiality considerations
[Developer]	No

9.3.2 Interview

Category	Questionnaire response
Are you seeing any improvement in your power take off design in terms of efficiency, size and cost? Provide examples where possible.	
[WTG OEM]	There is now increased reliability and improvements in this area. Converters are seen as a source of IP advantage by [WTG OEM]. They feel that their UK designed converter technology is incredibly sophisticated and advanced. In particular the advantage is achieved by sophisticated software. It may also be nice to think that in future it would be possible to bring some of the manufacturing of this kit into the UK as well, which is further out, but something which is being considered.
Are you aware of turbine OEMs offering improved power convertor systems on new turbine products (e.g. condition monitoring or new materials for power convertors)? If so please provide details.	

[WTG OEM]	Not aware of any new materials, a lot of the developments into R&D has been into how to control and write software to handle power electronics. As an organisation, there is a lot of interest in creating synthetic inertia through sophisticated control of convertors, which is almost all enabled by clever software.

9.3.3 Market intelligence

Evidence	Source
• MHI Vestas Offshore Wind has received an order from Vattenfall to supply turbines and services for the 406 MW Horns Rev 3 wind power plant off the west coast of Denmark. The order for 49 V164-8.0 MW turbines includes a five year full scope service contract to optimise power production. The V164-8.0 MW turbines – rated with a capacity of 8 MW – have been optimised for the Horns Rev 3 project, utilising a power mode to be able to deliver a maximum output of 8.3 MW, further increasing the value for the customer. CEO Jens Tommerup said that “the use of an 8.3 MW power mode with the large 164 m rotor diameter provides an optimised rotor to generator ratio, demonstrating our ongoing focus on improving our technology, continuing to maximise value for our customers”.	http://www.mhivestasoffshore.com/mhi-vestas-offshore-wind-receives-406-mw-order-denmark/

9.4 Additional comments

None for this indicator

9.5 Recommendations

None for this indicator

10 Optimisation of Rotor Diameter to Rated Capacity

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Rotor	Optimisation of Rotor Diameter to Rated Capacity

10.1 Summary Analysis

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

Finding: Behind target

Marked as 'behind target' in 2016 because there is no firm evidence of any of the current fleet of offshore turbines in the 6 – 8MW class expecting to release products with increased rotor diameters in the near future. A methodology defining optimised rotor diameters was developed as part of the 2012 CRP study published by TCE. Using the metric from CRP and CRMF 2014 the only commercially available turbines deemed to have a rotor diameter close to optimised for generating capacity are the Siemens SWT4.0-130 and SWT 6.0-154. In assessing this indicator this year it is clear that less than 50% of turbines contracted have 'optimised' rotor diameter, as only two projects have reached FID based on these turbines in the period of this study, (Arkona, Tahkoluoto). As such turbines with optimised rotor diameter represent only 8.44% of the MW or 9.90% of the number of turbines reaching FID in the period of this study. All other EU projects achieving FID in the past 12 months have been based on turbines with a rotor diameter smaller than would be considered 'optimised' by the CRP methodology. This indicator represents a potential for LCOE reduction from the increased AEP which would be available for a turbine with

a larger rotor diameter, accepting that at some point the structural challenges associated with increased swept area cause the convergence on an optimum balance of the cost of executing a larger swept area and the potential AEP output.

Last year this indicator was scored as ‘on target’ based on a significant share of projects contracting turbines with ‘optimised’ rotor diameters, although there was some legacy of mature previous generation turbines in the 4 MW class influencing this result.

In previous generations of turbine platforms through the 2, 3 and 4 MW classes it has been common for turbine OEMs to release turbine products initially with what could be considered smaller than optimum rotor diameters, which are then followed with larger rotor diameters once experience is built and the platform reaches maturity. There is no reason to expect that this trend will not continue for the current generation of 6 – 8 MW turbines. As described in the ‘turbine rating’ indicator, turbine OEMs have made several announcements of incremental increases in individual turbine generating capacities, but none have made announcements about longer blades.

At present it is likely that blade design, materials, coating and manufacturing technology, as well as testing and certification requirements are all challenging the designers of blades seeking to develop the next generation of blades which will be of the order of 80 – 90 m in length.

Finally, a notable but yet to be produced turbine design relevant to this indicator is the Adwen AD8-180, which if build would represent a turbine platform with an optimum rotor diameter for the generator capacity at zero series, although the contracting of this turbine on a commercial project by 2020 is uncertain and perhaps unlikely.

Outlook:

The future of progress in this indicator could be expected to fall into one of two categories:

- Firstly, it could be that the continual evolution of technology in combination with innovations will permit the design and manufacture of longer blades for increased rotor diameters in the future.
- However it is equally possible that there could be that several years of projects developed with rotor diameters below what are considered by CRP or CRMF 2014 to be optimum for turbine generating capacities. It remains to be seen whether blade technology can progress at sufficient speed to keep up with progress in turbine rating and whether any turbine OEM will be able to make a step change in rotor diameter before 2020.

A ‘medium confidence’ in the future outlook for this indicator was expressed by industry. It is likely that rotor diameters will expand in the coming years, but it is not certain that the required increase from current state of the art will be achieved to enable ‘on target’ cost reduction contribution by 2020.

10.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	70% of turbines have optimised rotor diameter	80% of turbines have optimised rotor diameter	Almost all turbines (90%) have optimised rotor diameter	All turbines have optimised rotor diameter	All turbines have optimised rotor diameter
On target	>50% of turbines contracted have optimised rotor diameter	Majority (60%) of turbines contracted use optimised specific rotors for 4 MW, 6 MW and 8 MW (assumed to be 176 m)	70% of turbines have optimised rotor diameter	80% of turbines have optimised rotor diameter	All turbines have optimised rotor diameter
Behind target	<50% of turbines contracted have optimised rotor diameter	50% of turbines have optimised rotor diameter	Majority (60%) of turbines use optimised specific rotors for 4 MW, 6 MW and 8 MW (assumed to be 176 m)	70% of turbines have optimised rotor diameter	80% of turbines have optimised rotor diameter
Missed target	No 6 MW turbines being designed have	No 6 MW turbines planned to have	No 6 MW turbines planned to have	No 6 MW turbines planned to have	Majority (60%) of turbines use optimised specific

	optimised rotor diameter	optimised rotor diameter	optimised rotor diameter	optimised rotor diameter	rotors for 4 MW, 6 MW and 8 MW (assumed to be 176m)

10.3 Evidence

10.3.1 Questionnaires

Category	Questionnaire response
Please provide details of plans to release updated versions of any of your existing turbine products (e.g. increased rotor diameter)	
[WTG OEM]	[WTG OEM] has plans for a new offshore turbine in the 2020s. No further details can be given at this time
[WTG OEM]	7 MW versions with 154 m and 8 MW possibly with larger rotor
[WTG OEM]	Please see question 16

Please provide details of any plans you are aware of for turbine OEMs to release updated versions of their existing turbine products (e.g. increased rotor diameter) Are you aware of turbine OEMs expected to offer new (increased diameter) blade and rotor designs for existing product families?	
[Blades]	all major WTM offshore planning this
[Developer]	No
[Developer]	Yes, we are aware that new developments of turbine portfolio however some of which are new platforms and others are evolutions of existing platforms
Do you expect to use existing turbine products with increased rotor diameter on future projects (before 2020)?	
[Developer]	No
[Developer]	Not expected – current projects prior to 2020 will be with existing technology.

10.3.2 Interview

Category	Interview response
Provide details of plans to release updated versions of the existing turbine (e.g. increased rotor diameter)	

[Blades]	Most OEMs are now thinking that next generation will be in 9 – 12 MW size, and [Blades] do not anticipate any major problems in developing rotors up to ~220 m which would be required to support this kind of technology evolution. Expect that in early 2020's could expect next generation of turbines from major OEMs

10.3.3 Market intelligence

Evidence	Source
• MHI Vestas Offshore Wind has received an order from Vattenfall to supply turbines and services for the 406 MW Horns Rev 3 wind power plant off the west coast of Denmark. The order for 49 V164-8.0 MW turbines includes a five year full scope service contract to optimise power production. The V164-8.0 MW turbines – rated with a capacity of 8 MW – have been optimised for the Horns Rev 3 project, utilising a power mode to be able to deliver a maximum output of 8.3 MW, further increasing the value for the customer. CEO Jens Tommerup said that "the use of an 8.3 MW power mode with the large 164 m rotor diameter provides an optimised rotor to generator ratio, demonstrating our ongoing focus on improving our technology, continuing to maximise value for our customers".	http://www.mhivestasoffshore.com/mhi-vestas-offshore-wind-receives-406-mw-order-denmark/

10.4 Currently available turbines and 'optimum' rotor diameter

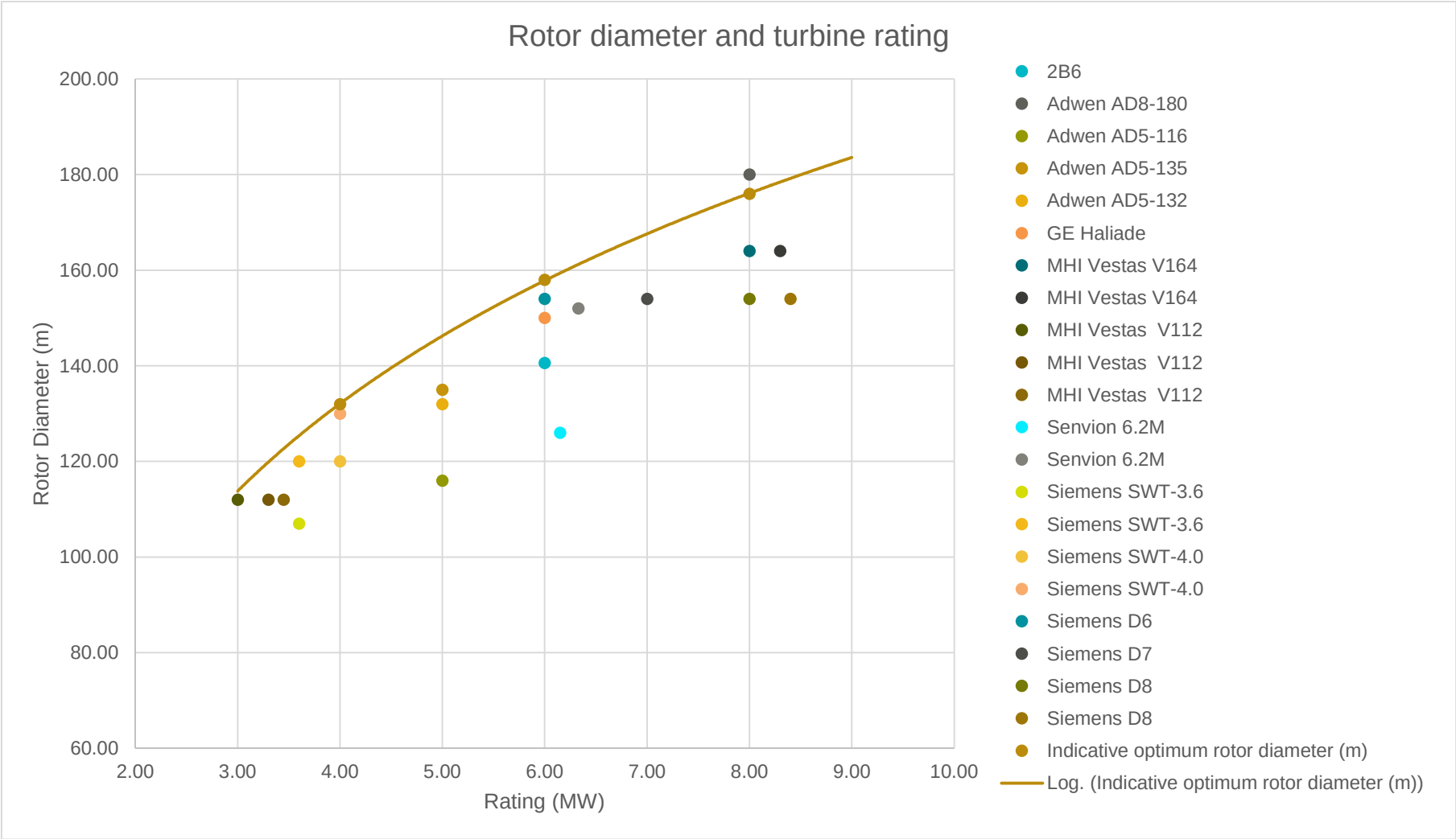

Figure 3 - Rotor diameter and turbine rating

10.5 Additional comments

None for this indicator

10.6 Recommendations

None for this indicator

11 Blade Design and Manufacture

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Rotor	Blade Design and Manufacture

11.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	Ahead of target	⇧	Medium confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because all turbine OEMs suggest (perhaps not surprisingly) that blade designs are being optimised for performance. At least one commercially deployed turbine in the current generation is designed with a tip speed of around 90 m/s. Several organisations are working on new and improved structural and fatigue blade testing techniques and manufacturers have built full scale prototypes of blades with radical (modular) structural design layouts. There have also been positive announcements and developments by turbine OEMs in blade manufacturing facilities, including two major OEM facilities in the UK.

Last year this indicator was scored as ‘on target’ citing many of the same developments which were at a less advanced stage than this year. In particular progress in blade coatings was highlighted as an area requiring improvement and focus.

There has been some consolidation, in particular the acquisition of Blade Dynamics and LM windpower by GE (who also acquired the Alstom offshore wind business). Potential restructuring of these businesses or wider implications for the blade design and manufacture industry are not yet fully understood.

Outlook:

Blade coatings and materials, in particular of relevance to leading edge erosion were highlighted as a particular concern in engagement in CRMF 2015. It is clear that the importance of this phenomena has become a priority for the industry, but long term cross industry development and resolution still remains somewhat uncertain with more research and development likely to be required. The outlook for existing and future blade design is also uncertain, although more than one OEM are anticipating investigation of modular or other novel blade design concepts. As such the outlook for this indicator is positive, although it is not yet certain that all of the achievements suggested in the 2020 vision will be achieved.

A ‘medium confidence’ in the future outlook for this indicator was expressed by industry, which reflects the uncertainty around some of the technology developments required in the coming years.

11.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Continuous improvement in aerodynamics through refined aerofoils and passive devices. Greater understanding of fatigue loading.	Continuous improvement in aerodynamics through refined aerofoils and passive devices. New blade manufacturing facilities now	Continuous improvement in aerodynamics through refined aerofoils and passive devices. New blade manufacturing facilities now	Blades with improved aerodynamics (aerofoils, modelling, passive devices) contribute a 1.3% improvement in AEP, materials and coatings,	Blades with improved aerodynamics (aerofoils, modelling, passive devices), materials and coatings, manufactured in improved processes

	Turbines with tip speeds of 90 m/s + available on market. New coatings, materials and composites being used on blades contracted. First full scale demonstration of novel structural design concepts.	operation leading to manufacturing cost savings. Holistic design tools well established and greater understanding of fatigue loading. Turbines with tip speeds of 90 m/s + available on market. New coatings, materials and composites being used on blades contracted. First full scale demonstration of novel structural design concepts.	operation leading to manufacturing cost savings. Holistic design tools well established and greater understanding of fatigue loading. Turbines with tip speeds of 90 m/s + available on market. New coatings, materials and composites being used on blades contracted. First full scale demonstration of novel structural design concepts.	manufactured in improved processes and to improved standards. Turbines with tip speeds of 100 m/s have a third of the market. Advanced coatings and materials on all turbines.	and to improved standards. Tip speeds will increase to 100 m/s on 80% of the market
On target	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available	Continuous improvement in aerodynamics through refined aerofoils and passive devices. Greater understanding of fatigue loading. Turbines with tip speeds of 90 m/s + available on market. New coatings, materials and	Continuous improvement in aerodynamics through refined aerofoils and passive devices. New blade manufacturing facilities now operation leading to manufacturing cost savings. Holistic design tools well established and	Continuous improvement in aerodynamics through refined aerofoils and passive devices. New blade manufacturing facilities now operation leading to manufacturing cost savings. Holistic design tools well established and	Blades with improved aerodynamics (aerofoils, modelling, passive devices) contribute a 1.3% improvement in AEP, materials and coatings, manufactured in improved processes and to improved standards. Turbines with tip speeds of

		composites being used on blades contracted. First full scale demonstration of novel structural design concepts.	greater understanding of fatigue loading. Turbines with tip speeds of 90 m/s + available on market. New coatings, materials and composites being used on blades contracted. First full scale demonstration of novel structural design concepts.	greater understanding of fatigue loading. Turbines with tip speeds of 90 m/s + available on market. New coatings, materials and composites being used on blades contracted. First full scale demonstration of novel structural design concepts.	100 m/s have a third of the market. Advanced coatings and materials on all turbines.
Behind target	New blade facilities under construction. Turbines with tip speed of 80 m/s + on market. Large test rigs are testing larger blades.	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available	Continuous improvement in aerodynamics through refined aerofoils and passive devices. New blade manufacturing facilities now operation leading to manufacturing cost savings. Holistic design tools well established and greater understanding of fatigue loading. Turbines with tip speeds of 90 m/s+

					available on market. New coatings, materials and composites being used on blades contracted. First full scale demonstration of novel structural design concepts.
Missed target	Limited improvement on 4 MW turbines. Common use of aerofoils and passive devices. New blade manufacturing facilities reaching FID use improved layout design and automation. Some use of holistic, design optimisation tools and characterisation of the blades. Turbines with tip speed of 80 m/s+ available on market. New test rigs for 100 m+ blades operational. New coatings being tested	New blade facilities under construction. Turbines with tip speed of 80 m/s + on market. Large test rigs are testing larger blades.	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available.	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available.	Ongoing improvement to aerodynamic performance of blades. New self-healing coatings widely available.

11.3 Evidence

11.3.1 Questionnaires

Category	Questionnaire response
Does your current turbine products have design features that seek to optimise aerodynamics at the design stage? Please detail. / Are you aware of next generation turbine product design features that seek to optimise aerodynamics at the design stage? Please detail.	
[WTG OEM]	Yes - vortex generators
[WTG OEM]	Yes, aeroelastic blade design with 'dyno-tails' etc.
[Blades]	yes
[WTG OEM]	Yes, [WTG OEM]´s blade aerodynamic design was specially developed for achieving the top characteristics of the actual market.
[Developer]	No

Where will the blades for your offshore turbine product(s) be manufactured and is this a purpose built facility for this size of turbine?	
[WTG OEM]	At the [WTG OEM]-owned [COMPANY] facility in [LOCATION]
[WTG OEM]	Blade plant in [LOCATION] just coming on line. This will solely manufacture [PRODUCT] blades for UK and overseas projects supplementing existing production facilities in [LOCATION]. Initial capacity of 450 blades per annum, but capacity to increase.
[WTG OEM]	Existing plant in [LOCATION] has already undergone improvements to be capable of manufacturing [PRODUCT] blades. New capacity foreseen in [LOCATION] (purpose built).
Are you developing any coatings for blades? If so, what are these and when will these be ready for the offshore market? / Are you aware of any development of next generation coatings for blades? If so, what are these and when will these be ready for the offshore market?	
[WTG OEM]	We use 3rd party coatings generally
[WTG OEM]	Continual improvement process rather than radical change. Leading edge protection techniques improving considerably

[Blades]	yes [PRODUCT]
[WTG OEM]	Confidentiality considerations
[Developer]	Leading edge coating/material - 2017/18
[Developer]	Turbine suppliers are developing leading edge erosion / protection. With rotor diameters increasing and tip speeds, it's imperative that the leading edge protection exists and is developed with the increasing demands of larger blades.
Discuss any other ongoing cost reductions in the design and manufacture of blades that you are aware of. For example innovations in structural design/concept, materials or automated manufacture.	
[WTG OEM]	[WTG OEM] blade manufacturing is constantly being optimised for yield and efficiency of production
[WTG OEM]	2 blades instead of 3!
[Blades]	Yes - we developed unique use of Carbon/glass - Hybrid material for offshore blades
[WTG OEM]	Research papers published in Europe and US

[Developer]	None
What orders for offshore wind turbine blades do you think you will sign this year in Europe and for which of your products? Provide details of projects and any framework agreements that you have signed.	
[Blades]	Many

11.3.2 Interview

Category	Interview response
What is your next generation of turbine offering likely to be in terms of MW size, rotor diameter, drive train concept, tip speed, design life? What stage of development is this turbine at? (e.g. design, prototype, etc)	
[Blades]	There are three areas, Size of turbine and blades associated: when talking about UK offshore, most turbines were less than 140 m rotor, but recently turbines with 154 m rotor by [WTG OEM], very recently [WTG OEM] have installed 164 m rotors. As this rotor size increases it has a strong potential to reduce cost of energy. [WTG OEM] have announced an 180 m rotor, which is a further validation of increasing size of rotor driving down LCOE, manufacturer claims that [WTG OEM] could reduce LCOE by another 8 – 10% against current generation of turbines.

	Design of rotors, as technology is moving, so is the efficiency of the rotor blades. This means that capability and innovations on rotor blade design are enabling the capture of more energy or with greater efficiency. Some improvements in both aerodynamic profile and by adding some specific features to the blades. Larger blades and rotor manufacture have until now required (on paper) carbon fibre, which is prohibitively expensive. [Blades] have recently announced a 'hybrid' carbon fibre which allows reduced manufacturing costs, and so can unlock some of the structural potential of a carbon fibre blade. Carbon is used to increase blade strength and make it thinner and lighter. Hybrid carbon incorporates these useful features of carbon, but at a much lower cost than a pure carbon blade. This is a recent new innovation announced by [Blades].
Does your next generation turbine product have design features that seek to optimise aerodynamics at the design stage? Please detail.	
[WTG OEM]	Obviously seeking to optimise aerodynamic efficiency, it is unlikely that any blade designer will respond otherwise to this indicator/question. [WTG OEM] believe that they have taken a different approach to other OEMs, they see it as core to their IP to retain control of aero elastics etc. in house and an advantage to keep control of this and seek to look at the turbine as a complete system in this way, rather than outsourcing too much design/manufacture/risk to the supply chain.
Where will the blades for your offshore turbine product(s) be manufactured and is this a purpose built facility for this size of turbine?	

[WTG OEM]	Will get a good run of production from [LOCATION], [WTG OEM] have a good pipeline of projects all requiring the [PRODUCT] blades. All projects into 2021 will be building this blade. Beauty of this facility is that it will only make a single product. This simplification has really helped to give confidence in using same tools, quality etc. There is 5 years steady production, which is a good production schedule, and being able to focus on making just one single product as efficiently as possible is a real strength of the facility.
Are you developing any coatings for blades? If so, what are these and when will these be ready for the offshore market?	
[WTG OEM]	Leading edge erosion is a particular focus and is improving, to date protection has been the issue. [WTG OEM] are looking at silicone based films and coatings that can either come into production process or be retrofitted. They have achieved significant learning from earlier wind farms and turbines which have fed into making improvements. The application of new generation leading edge protection is now more or less standard in manufacturing/production phase. It is of course very topical for their customers who are keenly aware of what issues have been and are keen to avoid similar in future on new projects.
Discuss any other ongoing cost reductions in the design and manufacture of blades. For example innovations in structural design/concept, materials or automated manufacture.	
[WTG OEM]	There is very much an attempt in [LOCATION] to start with a fresh sheet of paper, not just copy how blades have been made so far, but rather to start at the beginning and design a process for how best to plan and run a factory. [WTG OEM] wind have been drawing on other [WTG OEM] group expertise outside of wind to build and operate a state of the art factory environments and help to automate and improve. Blade build is labour intensive and will always require significant skilled manual input. Blade at [WTG OEM] is cast in a single unique piece, which may have to change if there is a need to get back to say a 100 m blade in future. Segmented or

	two piece blades may have to come back. Process may have to change to make even bigger blades as there must be fundamental physical limits to the manufacture of single castings this large.

11.3.3 Market intelligence

Evidence	Source
• On 02/09/16 offshore wind turbine manufacturer Adwen and turbine rotor blades supplier LM Wind Power have unveiled the world's longest wind turbine blade. The 88.4 m long blade has been designed for Adwen's AD 8-180 wind turbine, an 8 MW wind turbine with a 180 m rotor diameter. This large blade was manufactured at LM Wind Power's factory in Lunderskov in Denmark.	http://www.maritimejournal.com/news101/marine-renewable-energy/adwen-produces-worlds-largest-blade
• The world's largest wind turbine has been installed off the coast of Liverpool, the manufacturer MHI Vestas announced on September 2016. The turbine is the first of 32 set to be installed at DONG Energy's 258 MW Burbo Bank Extension offshore wind project. The event marks the first time the enormous V164 8 MW wind turbine has been installed anywhere in the world. The turbines have a swept area of over 21,000 m^2, larger than the London Eye, and 80 m long blades each weighing 35 tonnes. The blades are also the first locally built blades to be installed at a UK offshore wind power plant, having been designed, tested and manufactured at MHI Vestas' factory on the Isle of Wight, the firm said.	http://www.businessgreen.com/bg/news/2470309/worlds-biggest-wind-turbine-installed-at-burbo-bank-offshore-extension

• On 08/02/2016 A Sandia's research on the extreme-scale Segmented Ultralight Morphing Rotor funded by the Department of Energy's ARPA-E program, designed a low-cost offshore 50 MW turbine requiring a rotor blade more than 650 feet (200 m) long significantly longer than any existing wind blade.	http://energy.gov/articles/enormous-blades-offshore-energy
• On 19/09/2016 The Offshore Renewable Energy (ORE) Catapult established a Wind Blade Research Hub seeking to collaborate with a UK-based University to accelerate offshore wind turbine blade research and development activities.	http://www.offshorewind.biz/2016/09/19/ore-catapult-setting-up-wind-blade-research-hub/

11.4 Additional comments

None for this indicator

11.5 Recommendations

None for this indicator

12 Control

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Rotor	Control

12.1 Summary Analysis

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

Finding: Behind target

Marked as ‘behind target’ in 2016 as there has been limited evidence of advancements in control at either an individual turbine or wind farm wide level. While individual OEMs undoubtedly continue to improve their own individual control strategies there is limited evidence of improvement beyond the research and development captured by CRMF 2015.

Last year this indicator scored ‘on target’. There was evidence of one turbine OEM investigating and applying wind farm wide control for wake management at demonstrator and a subsequent commercial project. There was some evidence of ongoing testing of turbine mounted lidar for control, but no evidence of strong interest from turbine OEMs, who are the gatekeepers of wider adoption of this technology.

Whilst many research projects have been conducted and are underway relating to the control of wind turbines and wind farms these tend to be academic or research focussed and appear to have seen little interaction from turbine OEMs. At the same time turbine OEMs do

continue to evolve their control strategies, but this is a highly proprietorial area of the market, and as such any improvements tend to be commercialised and offered as an upgrade with a cost. At least one customer describes adoption of control upgrades without yet being aware of the cost benefit (through increased production or reduced loads) of doing so.

Outlook:

There is significant potential for future improvement in this area. As turbines and wind farms become more data rich, and in future as the topics of lifetime management or economical and well informed life extension become more relevant it is likely that there will be an increasing focus on control system optimisation for both energy production and loads.

It looks likely that turbine mounted lidar will increasingly be relied upon for independently analysing the performance of turbines by developers/operators. However integration with the control system in the spirit envisaged by this indicator looks unlikely by 2020 or beyond, as turbine OEMs are not incentivised to enable this technology improvement.

There are also further potential advancements in the deployment of wind farm wide control and/or in more intelligent interactions between wind farms and the grid, enabled by better control.

Aerodynamic control actuators are a technology suggested in the suggested 2020 vision that look particularly far off at present.

A ‘medium confidence’ in the outlook for this indicator was expressed by industry, reflective of the remaining potential and the fact that some technical advances may be restricted by commercial factors.

12.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Ongoing improvements with control algorithms.	Ongoing improvements with control algorithms.	Ongoing improvements with control algorithms.	All turbines use modern multivariable predictive control	All turbines use modern multivariable predictive control

	At least three wind farms using wind farm wide control systems. First blades using local aerodynamic control devices are contracted.	First blades using local aerodynamic control devices are operational	Wind farm wide control systems becoming standard practice and delivering benefits. First blades using local aerodynamic control devices are operational.	algorithms, which contribute to wind farm wide control approaches. Turbine mounted Lidar installed on a significant number of turbines. At least two turbines have novel aerodynamic control actuators.	algorithms, which contribute to wind farm wide control approaches. Turbine mounted Lidar installed on a significant number of turbines. At least two turbines have novel aerodynamic control actuators.
On target	Ongoing incremental improvements with control algorithms. R&D initiatives underway testing wind farm wide control systems. New aerodynamic control actuators are included in turbine design. First turbine mounted Lidar installed on an offshore turbine for testing	Ongoing incremental improvements with control algorithms. At least three wind farms using wind farm wide control systems. First blades using local aerodynamic control devices are contracted.	Ongoing improvements with control algorithms. First blades using local aerodynamic control devices are operational. Wind farm wide control being used on 75% of projects	Ongoing improvements with control algorithms. Wind farm wide control systems becoming standard practice and delivering benefits. First blades using local aerodynamic control devices are operational.	All turbines use modern multivariable predictive control algorithms, with turbine mounted lidar integrated with control systems on a few turbines. Local aerodynamic control devices used. Integrated wind farm wide control systems are utilised on some projects.
Behind target	Limited improvements with control algorithms. First wind farms start controlling at wind farm level.	Limited ongoing improvements with control algorithms. R&D initiatives underway testing wind farm wide	Ongoing improvements with control algorithms. At least three wind farms using wind farm wide control	Ongoing improvements with control algorithms. First blades using local aerodynamic	Ongoing improvements with control algorithms. Wind farm wide control systems becoming standard

	Lidar tests planned on offshore turbines	control systems. New aerodynamic control actuators are included in turbine design. First turbine mounted Lidar installed on an offshore turbine for testing	systems. First blades using local aerodynamic control devices are contracted.	control devices are operational	practice and delivering benefits. First blades using local aerodynamic control devices are operational.
Missed target	No improvements with control algorithms	No improvements with control algorithms	Ongoing improvements with control algorithms. R&D initiatives underway testing wind farm wide control systems. First blades using local aerodynamic control devices are contracted. First turbine mounted Lidar installed on an offshore turbine for testing	Ongoing improvements with control algorithms. R&D initiatives underway testing wind farm wide control systems. First blades using local aerodynamic control devices are contracted. First turbine mounted Lidar installed on an offshore turbine for testing	Ongoing improvements with control algorithms. First projects use wind farm wide control systems. First blades using local aerodynamic control devices are operational

12.3 Evidence

12.3.1 Questionnaires

Category	Questionnaire response

Describe any improvements in wind turbine control systems that you have implemented within the past year?	
[WTG OEM]	TBC
[WTG OEM]	[PRODUCT], and [PRODUCT] facilities for AEP increase routinely offered to customers.
[WTG OEM]	New and improved control system for [PRODUCT]
[Developer]	None
Is your organisation moving towards utilising wind farm wide control systems (i.e. using the individual WTG control systems to minimise loads/wakes across the wind farm)? If so, please detail your progress.	
[WTG OEM]	TBC
[WTG OEM]	Exploring and R&D stage but not yet available as a product
[WTG OEM]	Confidentiality considerations
[Developer]	Currently at early stages of project planning for this technique. Will be run through [Developer]'s involvement in industry R&D programmes

[Developer]	With upcoming projects, wake analysis has been conducted however significant separation in turbine rows has been the primary focus to allow us to maximize AEP.
Have you used turbine mounted lidar in a control system? Are you involved in any research or projects? If so please provide details.	
[WTG OEM]	Yes, [WTG OEM] has looked at this. The development of this will be customer-led. If enough customers and/or projects need this, we'll develop a solution to this
[WTG OEM]	Some customers deploying turbine mounted Lidar, but still at R&D stage
[WTG OEM]	Confidentiality considerations
[Developer]	No
Are you aware of any commercial projects that are utilising turbine mounted lidar in a control system? Are you involved in any research or projects? If so please provide details.	
[Lidar]	I am not aware of commercial projects using the turbine mounted lidar to control the turbine. There are several projects looking at this, form basic principles through to those aiming to have some control. There is some information in the public domain e.g. Alstom's "Development, Field Testing, and Evaluation of LIDAR-Assisted Controls" with the US Department of Energy involvement this has been published (and I think phase 2 is due for publication soon)

	There are two main markets; integration into the future products of WTG OEMs and the retrofitting onto the installed fleet. Both have considerable barriers to development and we have been working at this for many years
[Lidar]	N/A
[Lidar]	No. Yes. We are involved in the NiteOwl turbine mounted lidar and control project, in collaboration with Thales and Fraunhofer, and funded by InnovateUK.
Please detail any barriers to the wider exploitation of turbine mounted lidar for control.	
[Lidar]	In warranty the control of the turbine could only really be achieved in combination with the WTG OEM, this is then determined by any given WTG OEMs appetite for developing this and when they do it is at their pace Out of warranty there is still an understandable caution, any control would need to improve the efficiency of the system (overly twitching pitch/yaw controls could wear the system and expend excessive energy). Also any control would have ensure it reduced the wearing of the system rather than inadvertently increasing it, what seems obvious needs testing to ensure it is for the better and this takes time. For the answer below my only reservation is the timescale, I would sincerely hope we see some "out of warranty" controls by 2020 but I am unsure as to whether the WTG OEM integration would be launched by then
[Lidar]	N/A
[Lidar]	OEM acceptance of technology developed by non-OEM organisations.

Please detail any other novel approach to control which you are introducing or aware of.	
[WTG OEM]	TBC
[WTG OEM]	Not aware
[WTG OEM]	Confidentiality considerations
[Developer]	None
[Developer]	Nothing to detail

12.3.2 Interview

Category	Interview response
Describe any improvements in wind turbine control systems that you have implemented within the past year?	
[WTG OEM]	High wind ride through and power boost offered as options. HWRT was/is available on older machines. Power boost is related to smart converters, at certain times and certain conditions it can be used to squeeze a bit more out of the 6 MW than 6 MW. There is a grey area here about how this may affect the CfD process, for example if consented to get a 6 MW then boost it, how does the regime support what is effectively slight overproduction? Really it is just a control/electrical way

	to squeeze a bit more AEP, so could also be termed ‘AEP boost’ and considered in the same light as many innovations which can increase capacity factor/AEP.
[Developer]	High wind ride through and similar technical tweaks allows more lean (optimised for weight & site conditions) structures to be developed and built Suggest speak directly to supplier for specific information on turbine technologies
Is your organisation moving towards utilising wind farm wide control systems (i.e. using the individual WTG control systems to minimise loads/wakes across the wind farm)? If so, please detail your progress.	
[WTG OEM]	Wind farm wide control: this has to involve the wind turbine OEM, it cannot succeed without a turbine OEM on board as they are likely to be the only ones with sufficient access to control. [WTG OEM] have piloted and trialled wind farm wide control, but are not deploying it as of today. One thing that could be done is to slow turbines on leading edge to reduce wakes and generate more AEP overall. This and other techniques can be conceived which would either reduce loads (hence increase lifetime) increase production or both, contributing to lower LCOE. However it is likely that turbine level lidar would be required to achieve this, which looks unlikely from [WTG OEM].
Have you used turbine mounted lidar in a control system? Are you involved in any research or projects? If so please provide details.	
[WTG OEM]	It is unlikely that routine commercial deployment of wind farm wide control will be seen between now and 2020.
Please detail any other novel approach to control which you are introducing.	

[Developer]	What they have seen in control is that there has been a lot of work on power curve optimisation. On the tail of the power curve, high wind ride through when close to cut off speed. [Developer] have upgraded control system on [PROJECT], but are not yet certain of a detectable benefit or have yet see that this has really delivered results.
[Developer]	Advanced turbine technology allows us to sell more services to support the grid, e.g. ancillary services. This helps to reduce the cost of OSW and also reduces the impact of having increased levels of variable renewables on the network.

12.3.3 Market intelligence

Evidence	Source
• In August 2016, Envision presented the smart energy management software which unites data from every asset to enable alerts, control and monitoring from a streamlined interface. Envision's wind farm solution module – Wind OS, allows for examining the real-time performance of each wind turbine on a farm, regardless of manufacturer and has been experimenting with several promising techniques for characterizing and managing wakes.	http://www.windpowerengineering.com/construction/simulation/optimizing-energy-production-addressing-rotor-wakes-wind-farms/

• CENER presented its system of closed loop identification algorithms able to main control loops of the wind turbines: torque loop, pitch loop, tower damping and drive train damping.	http://secure.cener.com/documentos/F_Control_Unit.pdf
• On 24/05/16 ECN announced that its Active Wake Control method is on track to boost wind farm lifecycle performance as the results of the feasibility studies were very promising (highlighting yield increases of up to 2%).	https://www.ecn.nl/news/item/ecn-active-wake-control-on-track-to-boost-wind-farm-lifecycle-performance/
• On 06/09/16 A ground-breaking study by the Wind Energy Institute at the Technical University of Munich (TUM) has used wind lidars originating from ZephIR Lidar to demonstrate the possibilities that total wind farm control offers the industry. Wakes were deflected along a line of wind turbines resulting in an increase of 15% actual power output from the combined wind farm production.	http://www.zephirlidar.com/wake-steering-results-15-power-increase-total-wind-farm-control-demonstration/
• The Farunhofer centre for applied photonics in the UK have several research projects related to lidar for wind turbine control	http://www.cap.fraunhofer.co.uk/en/ApplicationsBusinessFields/Inno

	vateUKProjects1.html

12.4 Additional comments

None for this indicator

12.5 Recommendations

None for this indicator

13 Integrated design (of turbine and support structure)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Integrated design	Integrated design (of turbine and support structure)

13.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Missed target	↓	▪ Low Confidence

Finding: Missed target

This indicator has been marked as ‘behind target’ for 2016 as there is no evidence of a project reaching FID based on a fully integrated design methodology. Whilst there was common understanding from developers and supply chain consultees alike that an integrated approach could offer significant cost reduction potential there was no evidence that commercial projects were expecting to take this approach. Some contributors described an increased understanding of the importance of transfer of information between (in particular) WTG OEM and foundation designer where a significant design interface exists, but in reality commercial constraints are limiting the potential of integrated design to contribute to cost reduction.

In CRMF 2015 this indicator was scored as ‘behind target’ noting similarly that whilst principles and advantages were understood, contractual structures and commercial decisions prevented the integration of design across packages.

Other developments which are relevant to this indicator are the announcements of a plan to demonstrate a novel hybrid jacket foundation design by Siemens, with many respondents suggesting that the only organisation likely to take integrated design forward (be offering a full contract scope) in the foreseeable future will be Siemens.

Outlook:

Whilst it is likely that some demonstration, trials and investigation of this concept will occur, potentially even resulting in a commercial offering in the future it is unlikely that any material benefit in terms of cost reduction will be experienced before 2020. The majority of contractors on the majority of projects will likely continue to progress non cost optimised designs are a result of contingencies and commercial pressures in the splitting up of contract scopes and a related reluctance to work collaboratively.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, which appears unjustifiably optimistic. It is unlikely that tangible cost reduction will be contributed by this indicator by 2020, and it is almost certain that a majority of projects will not be working on integrated design of turbine and support structure by 2020. Accordingly ORE Catapult have adjusted the outlook for this indicator to ‘low confidence’.

13.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	First project under construction using integrated design. At least one other project contracts using the approach.	First project operational using integrated design. Integrated design used for 50% of contracted projects	Integrated design used for more than half of projects	Integrated design used for 80% of projects reaching FID	Integrated design is universal.

On target	One project under construction using integrated design. Others looking to contract using the approach	First project under construction using integrated design. At least one other project contracts using the approach.	First project operational using integrated design. Integrated design used for 50% of contracted projects	Integrated design used for more than half of projects	Integrated design used for 80% of projects.
Behind target	One project uses integrated design principles and reaches FID	One project under construction using integrated design. Others looking to contract using the approach	First project under construction using integrated design. At least one other project contracts using the approach.	First project operational using integrated design. Integrated design used for 50% of contracted projects	Integrated design used for more than half of projects
Missed target	Principles understood and considered in FEED.	One project used integrated design principles	One project under construction using integrated design. Others looking to contract using the approach	First project built using integrated design. At least one other project contracts using the approach.	Integrated design used for 25% of projects

13.3 Evidence

13.3.1 Questionnaires

Category	Questionnaire response
Do you plan to integrate the design of the turbine and support structure on your projects?	

[WTG OEM]	Yes, [WTG OEM] already does this for all their offshore projects
[Foundation]	Yes, absolutely
Designer / Survey	N/A
[WTG OEM]	In response to customer demand
[Developer]	Yes, we see this as an area of optimisation, both in the design process and the improved development of input site conditions parameters. We have some R&D initiatives looking at novel substructure design and are active in projects to improve foundation design codes (e.g. PISA).
[Developer]	We typically seek to do this already on our offshore projects and have used 3rd party advisors to conduct the integrated modelling approach with WTG suppliers input.
Please note any FEED studies you have been involved with that have considered fully integrated design of the turbine and support structure? i.e. full numerical models from tip to pile with modifications to the turbine to save costs in the support structure.	
[WTG OEM]	This has been carried out on all our offshore projects - [PROJECT], [PROJECT], [PROJECT] , [PROJECT], [PROJECT]
[WTG OEM]	[WTG OEM] is piloting innovative foundation concept on a demonstrator project.

[Foundation]	Fully integrated design is usually not performed at FEED stage.
Designer / Survey	N/A
[WTG OEM]	Studies on going
[Developer]	To date design of the WTG and support structure has been iterative between the parties to optimise the overall structure. This approach is acknowledged to be potentially inefficient.
Do you have plans to introduce this methodology on future projects?	
[WTG OEM]	It's already in place
[WTG OEM]	still at R&D stage and dependant on customer approach
[Foundation]	Yes
Designer / Survey	N/A
[WTG OEM]	Confidentiality considerations

Are you doing much work around integrated design? If so, please detail. (e.g. developing your own support structure design)	
[WTG OEM]	[WTG OEM] works with the chosen foundation designer on a project-specific basis
[WTG OEM]	see above
Designer / Survey	N/A
[WTG OEM]	Confidentiality considerations
[Developer]	We are following the development in this area closely.
[Developer]	Nothing to report
Are there any barriers preventing you from adopting a fully integrated design methodology for the entire turbine and foundation assembly? Please discuss.	
[WTG OEM]	No. We have the team in place to achieve this already
[WTG OEM]	Contracting model of Developers
[Foundation]	The main barrier remains Customer multi-contracting approach. EPCI approach would allow a better design methodology.

Designer / Survey	N/A
[WTG OEM]	Contract strategy
[Developer]	Engagement by the OEM's is a pre-requisite to adopting a fully integrated foundation design. Currently we do not see much appetite from the OEM's to adopt a change in the conventional approach to foundation/tower design, which leads to suboptimal designs as the WTG OEM may seek to reduce tower stiffness/weights and the foundation designer may seek to do the same to the foundation, without the two parties collaborating in the interests of an overall optimised structure. There is considerable room for improvement here.
[Developer]	No barriers that we are aware of. This is not done in house and usually through a 3rd party. The main question is what software to use.

13.3.2 Interview

Category	Interview response
Please note any FEED studies you have been involved with that have considered fully integrated design of the turbine and support structure? i.e. full numerical models from tip to pile with modifications to the turbine to save costs in the support structure.	
[WTG OEM]	[LOCATION] demo project is about trying new things and finding non turbine areas to drive out costs.

	Demo site has gravity jacket, hybrid design. Not too much in the way of specific information but does also feature a concrete transition piece.
[Designer]	This area is improving. Within the last 5 years [Designer] have attempted to take an integrated design approach on foundation design. [Designer] are increasingly working with turbine OEMs to improve foundation design through an integrated approach. An iterative series approach is generally taken i.e. [Designer] perform load calculations on the foundation which are passed onto the OEM who performs turbine load calculations which are fed back to [Designer], and so on. Time is money and therefore the current opportunity is to optimise the speed of this series process. The biggest opportunity for optimisation is to make the foundation and turbine design a parallel process, however it would need a large OEM to make a move in this area as they are so sensitive of their turbine design data.
Do you have plans to introduce this methodology on future projects?	
[WTG OEM]	Because of the [WTG OEM] focus on LCOE there have been many developments in turbine technology, to try and get 70 – 80 euro cents, the kind of cost of energy that much of our industry have stated that they are aiming for.
Are you doing much work around integrated design? If so, please detail. (e.g. developing your own support structure design)	
[Developer]	There is clear evidence of improvement in this area. On the [PROJECT] project with innovative foundation designs there has been a notable and valued approach to sharing of information and designs across design interfaces.

	There has been good transparency and sharing of information across foundation and turbine OEM. This is an effect that there is more awareness of the risk of not having this, perhaps particularly so when considering somewhat novel foundation designs. For example on [PROJECT] [Developer] had some structural issues associated with a poor design of the interface, the OEM now understand that it is in their interest to go fully through the design load interactions more collaboratively. GBS reduces the closed mind-set as it is clear that expertise from each side needs to work together, and there may be limited experience of concrete/civils inside of even the largest turbine OEMs. Recently [WTG OEM] have taken one full EPC, could imagine [WTG OEM] doing it but couldn't imagine anyone else doing it, wouldn't expect that [WTG OEM] would be able/willing to take the step towards fully integrated design in the sense of this indicator.
[Foundation]	Have not heard any evidence of weight reduction from the tower through the use of jackets, but think it must exist. [WTG OEM] have undertaken research on this topic. An interesting case is two non-operational projects that have reached FID that are using the same turbines in similar water depths where a three legged jacket is 200 t lighter than a four legged jacket. The reason for this discrepancy is unknown but it potentially highlights the lack of integrated design between the turbine and substructure that takes place.
Are there any barriers preventing you from adopting a fully integrated design methodology for the entire turbine and foundation assembly? Please discuss.	
[WTG OEM]	However there is only so much that can be achieved if working on the turbine alone. Innovative foundations and cable in pipe etc. all show promise for LCOE reduction. If they were really in a partnership with a committed developer then it might be easier to do this by really collaborating and sharing design information. Most of projects that [WTG OEM] are working on now have been through a lot of scoping, design, support contract bidding etc. before they even decide what turbine they

	will be using. This type of approach can add significant cost to the project at the interface between turbine OEM scope and other design and development work. [PROJECT] can be seen as an illustrative example; the procurement process had selected a different turbine, but [WTG OEM] came in and suggested that both parties collectively work to make there be a viable business case with [WTG OEM] as turbine OEM, a partnership approach like this can really help to drive out cost across the whole project, not just in individual packages/scopes. Developers may often think that competitive tension is the best way to get the lowest price, but a lot of cost can be removed from projects by really working in partnership at earlier stages. Despite some good examples of OEM and developer getting together this is not the norm and [WTG OEM] feel that more could be done if a way round this barrier/mind-set could be found.

13.3.3 Market intelligence

Evidence	Source
• On 08/02/16 Swedish company Hexicon appointed Atkins as engineering partner for the world's first multi-turbine offshore wind floating platform to be deployed at the Dounreay Tri Project off the Scottish north coast. Chris Cowland, project director in Atkins' renewables business stated: "The integrated design capability that enables the head to toe design that we're undertaking for Hexicon clearly demonstrates how our experience across a range of both floating and fixed offshore wind projects can add real value to clients."	http://www.atkinsglobal.co.uk/en-GB/media-centre/news-releases/2016/feb/2016-02-08

• On 16/05/2016 The 30 MW project, called Hywind, is hailed as a solution to the problem of tapping into the North Sea's huge wind-energy potential without the high cost of fixing turbines to the seabed in deep water. Statoil will use its proprietary pitch-motion control system which is integrated with the turbine's control system to mitigate the loss of generating capacity caused by excessive wave motion.	http://www.globalconstructionreview.com/news/scotland-get-worlds-biggest-flo7ating-win7d-far7m/
• In September 2016, the Wind Power and Renewables division of German multinational Siemens will provide four 7 MW wind turbines with accompanying new offshore wind innovations to a pilot offshore wind project being developed in northern Denmark. Siemens will not only supply the four 7 MW wind turbines, but will also supply an innovative and new cost efficient gravity jacket foundation solution, the company's new 66 kV voltage solution including a new transformer, cable and switchgear systems, and further tower and controller innovations. Michael Hannibal, CEO Offshore at Siemens Wind Power and Renewables Division said that "Since the Danish Ministry of Energy tendered the project as an official test bed for new technologies and integrated design, we've looked forward to this exciting project. This gives us the opportunity to simultaneously test and promote our innovations to achieve further cost reductions in offshore wind."	http://cleantechnica.com/2016/09/21/new-28-mw-pilot-offshore-wind-farm-benefit-siemens-innovations/
• Siemens have announced a demonstration scale project in Denmark which will feature an innovative concrete transition piece (TP), four-legged, trussed steel jacket with "industrialised" nodes and suction bucket bases, and built-in high-voltage cabling, transformers and switch-gear. It will use 7 MW turbines and 66 kV cabling.	http://www.rechargenews.com/wind/1185912/siemens-joined-up-thinking-to-cut-offshore-wind-costs

13.4 Additional comments

None for this indicator

13.5 Recommendations

None for this indicator

14 Turbine design

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Turbines	Design	Turbine design

14.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
N/A	On target	N/A	High confidence

Finding: On target

Marked as ‘on target’ in 2016 because there is evidence from both turbine OEMs and developers suggesting that turbine design in current and future generations of turbines have been designed with a more holistic approach. That is to say that maintenance activity or safety issues inherent in previous turbine platforms which were responsible for significant cost impact have been considered and largely mitigated at the design stage for current WTG. Specific evidence around turbine OEMs involving O&M teams at an early stage in the turbine design process and public statements around the design of turbine nacelle layouts to make major offshore maintenance easier support the finding that there has been an improvement and potential LCOE reduction contribution here.

This is a new indicator for 2016 and as such a rating from previous CRMF studies does not exist.

Tempering the progress in this area somewhat, there have been recent announcements by turbine OEMs and developers of significant cost and effort being invested in major repair of relatively new offshore turbines, including the recovery of compete nacelles to port for repair work. Whilst this indicator does not necessarily seek to describe improvements in individual component reliabilities, it is suggested that had major component replacement been given a higher priority at the design stage it may have been possible to mitigate or avoid some of the high costs of reactive offshore campaigns.

Outlook:

There is more potential for improvement in this area, with at least one developer suggesting that whilst turbine designs have improved significantly, there may still be decisions taken by a turbine OEM which prioritise the ease of manufacture over through life maintenance or safety performance. There have been suggestions that the design focus may still be too focused on CAPEX reduction at the expense of considering OPEX cost implications, although it is likely that there will be a continuing trend towards improved designs as the level of operational phase experience increases.

A ‘high confidence’ was expressed by industry in the outlook for this indicator. Note that the score was very close to ‘medium confidence’ and as such the fact that effort is required to unlock remaining potential cost reduction is suggested.

14.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Majority of turbines on the market exhibit design features which are specifically targeted at easing	Two or more turbines on the market exhibit design features which are specifically targeted	Majority of turbines are fully optimised in design for maintenance activities, are maintained with	Significant reductions in OPEX are expected by OEMs offering products which can be maintained more	Significant reductions in OPEX are proven by OEMs offering products which can be maintained more

	maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven increased and/or dynamic service intervals.	at easing maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven increased and/or dynamic service intervals.	interventions at dynamic intervals and have reduced the workload for statutory inspections and require less safety equipment.	easily, which can be accessed less frequently and have a reduced requirement for statutory inspections.	easily, which can be accessed less frequently and have a reduced requirement for statutory inspections.
On target	At least one turbine available on the market has substantial design features which are intended to reduce maintenance effort. Evidence of some design features which increase personal safety.	More than one turbine on the market exhibit design features which are specifically targeted at easing maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven	Majority of turbines on the market exhibit design features which are specifically targeted at easing maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven increased and/or	Majority of turbines are fully optimised in design for maintenance activities, are maintained with interventions at dynamic intervals and have reduced the workload for statutory inspections and require less safety equipment.	All turbines designs are fully optimised for the life of the turbine. Maintenance activities and frequencies are considered at the design phase based on test and field validation of intervals between interventions.

		increased and/or dynamic service intervals.	dynamic service intervals.		
Behind target	Design for maintenance is conceptually discussed and understood, but has seen limited uptake.	One turbine available on the market has substantial design features which are intended to reduce maintenance effort. Evidence of some design features which increase personal safety.	Two or less turbines on the market exhibit design features which are specifically targeted at easing maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven increased and/or dynamic service intervals.	Several turbines on the market exhibit design features which are specifically targeted at easing maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven increased and/or dynamic service intervals.	Several turbines on the market exhibit design features which are specifically targeted at easing maintenance effort. These could include deigns to allow up tower major component exchange, avoid requirements for jack up vessels, or us of individual components with tested and proven increased and/or dynamic service intervals.
Missed target	No evidence of design for maintenance or design for safety beyond minimum statutory requirements.	Design for maintenance is conceptually discussed and understood, but has seen limited uptake.	Design for maintenance is conceptually discussed and understood, but has seen limited uptake.	One turbine available on the market has substantial design features which are intended to reduce maintenance effort. Evidence of some design features	One turbine available on the market has substantial design features which are intended to reduce maintenance effort. Evidence of some design features

				which increase personal safety.	which increase personal safety.

14.3 Evidence

14.3.1 Questionnaires

Category	Questionnaire response
Do you feel that turbine design for maintenance is advancing towards a mature stage?	
[WTG OEM]	Yes. [WTG OEM]'s offshore turbines have been specifically designed to be easily maintainable, e.g. components can be easily removed etc.
[WTG OEM]	Yes much improved. Better design stage assessment of O&M implications. Adoption of Direct Drive largely as a result of reduced O&M cost - 50% of moving parts compared to previous generation geared turbines
[WTG OEM]	Yes
[Developer]	No
[Developer]	As technology is developing and the WTG designs are evolving, a large emphasis has been put on quality of suppliers and sub suppliers. This ensures the reliability exists within the turbine.

	That being said, the turbines are becoming very “O&M friendly” to ensure when something does go wrong that maintenance can be conducted in a safe and easy manner.
Are you aware of any projects seeking to design turbine products that are specifically optimised to minimise maintenance procedures/costs? (e.g. design for simple major component exchange)	
[WTG OEM]	Yes
[WTG OEM]	Yes - our product incorporates a number of novel M&O approaches (e.g. integrated helideck on each turbine for M&O purposes, integrated central group transformer (powertown concept), modular design, 40 year design life, etc.) which we intend to demonstrate at our Offshore Wind Demonstration site at [LOCATION].
[WTG OEM]	Turbines better designed for maintenance, but aim is to avoid major component changes, not make it easier.
[WTG OEM]	[PRODUCT]
[Developer]	No
How do you expect turbine design principles to change in the next 3 - 5 years?	

[WTG OEM]	The basic offshore design principles will not change too much (e.g. three bladed, horizontal axis, direct drive or geared etc.). The turbine capacity and rotor diameter will see the biggest changes.
[WTG OEM]	Will not change significantly
[WTG OEM]	Next generation >10 MW class machines under early consideration dependant on market
[WTG OEM]	Continuous improvement. New tools for next generation wind turbines (2025 horizon). New tools for floating.
[Developer]	Further development of 6 – 8 MW technology. 10 MW prototype.

14.3.2 Interview

Category	Interview response
Do you feel that turbine design for maintenance and design for safety (for example) are advancing towards a mature stage?	
[WTG OEM]	H&S driven greater consideration of what maintenance tasks will be into the design phase. Design risk assessments and so on.

	They involved service technicians much more in designing O&M layout etc. when working on the 6 MW platform. This is evident in the design that has come out of the process. [WTG OEM] are much better now at taking a more whole life view of how to make things more available, reduce downtime to drive down levelised cost. The big leap to direct drive was an ultimate expression of how to eliminate previously challenging maintenance activities.
[Blades]	Yes, when designing new blades, have absolutely been considering how to incorporate all the experience from previous smaller blades. Specific examples are large amount of data that exists in leading edge erosion, lightening etc. and have tried to use this learning and information to reduce the O&M costs, they are expected to need significantly reduced OPEX spend in future. Leading edge protection offered is now significantly more robust than it has been in the past. Specifically considering lightening protection, now lab test for a more than 10 year life between servicing interventions. Have been doing a lot of work in pioneering condition monitoring of leading edges, and have developed for example a lot of new R&D into coatings and so on. Expect that next blades produced will be very different to those which came before from and operation and maintenance point of view.
Are you aware of any projects seeking to design turbine products that are specifically optimised to minimise maintenance procedures/costs (e.g. design for simple major component exchange)	

[Developer]	Yes, [WTG OEM] for example are showing examples that there has been a lot of thinking and design that has been driven by O&M needs. There have been some very early conversations about for example evacuation systems where the turbine OEM seems to be thinking about operational considerations early in the design phase of products/projects. There is still probably some room for improvement, there are some elements where a turbine OEM gives priority to manufacturing, over for example maintenance or safety, there is more to be done here but it is better now that it would have been in a previous generation in terms of having a turbine designed for the full operational life. This is probably because developers/utilities are becoming more experienced and know more about what it is they are buying and what it will be like to operate them for a long time. They could perhaps be asking harder questions of OEMs when it comes to turbine supply. The industry and [Developer] as a developer do not yet have much tangible proof that critical components which have been redesigned for next generation will actually deliver all of the potential benefit in reliability and availability that is promised. Track record for all OEMs is still building.

14.3.3 Market intelligence

Evidence	Source
None for this indicator	

14.4 Additional comments

None for this indicator

14.5 Recommendations

None for this indicator

15 66 kV

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Array cables	66 kV

15.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016 because projects are known to be going ahead based on 66 kV array cable designs. There is evidence of a maturing market in the supply of cables with this rating and developers appear confident that they will achieve the necessary milestones in qualification and certification such that 66 kV cables will be deployed on projects in the near future. It is likely therefore that a significant percentage (although perhaps still the minority of projects because of a legacy of projects designed for 33 kV) of projects will be installing 66 kV by 2020.

The first UK project is expected to install 66 kV cables at demonstration scale in 2017, with larger projects following closely behind. The technology has also seen commitment for European projects. All turbine OEMs confirmed capability to support the requirements of 66 kV.

Last year this indicator was scored as ‘behind target’ primarily due to a lack of projects reaching FID with this technology.

Outlook:

Some scope for further improvement in this area does exist, for example there may at present be some constraints on suitably skilled labour for installation and commissioning of 66 kV, which will ease as the number of completed 66 kV projects increases. A positive improvement could also be envisaged in development of increased levels of competition, this could be both in the supply of cables themselves but also in associated terminations, accessories and connectors, again as the market matures it is anticipated that further cost reduction through competition and economies of scale will be achievable.

A ‘medium confidence’ was expressed by the industry in the future outlook for this indicator, reflecting the remaining journey for 66 kV projects to successfully go through deployment and enable confidence that the technology is proven from a practical point of view.

15.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Quarter of market using 66 kV	40-50%	60-70%	80-90%	All projects use 66 kV
On target	A third of the projects which contract use 66 kV cables	First project using 66 kV cables operational. A third of projects which contract use 66 kV	30-45%	40-60%	60% of projects use 66 kV
Behind target	FID reached on EU project using 66 kV cables	Second EU project reaches FID	<20%	Quarter of market using 66 kV	<40%
Missed target	No FID using 66 kV	FID reached on first EU project using 66 kV cables	0	0	<20%

15.3 Evidence

15.3.1 Questionnaires

Category	Questionnaire response
Discuss any barriers to your turbine being used with 66 kV array cabling.	
[WTG OEM]	None - offered currently and will be deployed on up-coming projects
[WTG OEM]	No technical barriers. The only barriers are commercial. We need a project pipeline to start the development work internally to certify such a solution. The design work has been carried out already.
[WTG OEM]	No major barriers apart from cost.
[WTG OEM]	None - Offered on all projects. Demonstrator projects underway
[WTG OEM]	[PRODUCT] output for grid at 33 kV on 66 kV.

[Installation]	N/A
[Developer]	Turbine voltage conversion to 66 kV, switchgear arrangement (mass & volume)
[Developer]	None
Please describe any related R&D projects you are involved with.	
[WTG OEM]	[PROJECT] will be a demonstrator of a number of technologies including 66 kV, innovative foundation, cable systems etc.
[WTG OEM]	None
[WTG OEM]	Confidentiality considerations.
[Installation]	Reducing weather downtime of cable installation. Utilization of AUVs for surveys. Fleet based modular emergency cable repair. Pre-termination of array cables.
[Developer]	Offshore wind accelerator
[Developer]	N/A

When do you think the first commercial scale 66kV array project will reach FID in the UK?	
[WTG OEM]	Soon - Demonstrators at [PROJECT] and [PROJECT] will be followed by commercial deployments.
[WTG OEM]	The [PROJECT] project off the coast of [LOCATION] will be the first offshore project built with 66 kV. However, the first large scale project will probably be [PROJECT] in 2019/20
[WTG OEM]	Don't know about the wider industry - we may use 66 kV for our larger 9 turbine demonstration array (due to be operational by the end of 2019)
[WTG OEM]	Already has. [PROJECT]
[WTG OEM]	[PROJECT] demonstration project
[Developer]	2018
[Installation]	We expect to see the first 66 kV cables in the water within 18 months.
[Developer]	When cost of foundation is low enough to accommodate the transformer and switchgear (estimate 2020).

[Developer]	[PROJECT] – FID 2016
Explain whether you are currently able to offer 66kV array cables to the market.	
[Installation]	We can install 66 kV cables.
[Developer]	We are not a manufacturer. However we do consider 66 kV and have sources of 66 kV equipment.
[Developer]	We are using 66 kV array cable on [PROJECT]
Are you considering 66kV array cables on your wind farm?	
[Installation]	Not a wind farm operator
[Developer]	We assess 66 kV to see cost justification vs 33 kV.
[Developer]	Yes – [PROJECT] will use 66 kV array cable
What are the barriers? E.g. lack of supply, technology demonstration.	
[Developer]	Cost to implement 66 kV system is higher than 33 kV system.
[Developer]	Product is available in the market

15.3.2 Interview

Category	Interview response
[Developer]	[Developer] can be certain that they will be the first UK installation of 66 kV array cables. The [PRODUCT] will be coming with 66 kV kit installed Although [Developer] are comfortable that the industry should now move to 66 kV their next projects in for example French projects are likely to continue to be planned based on 33 kV, it is an evolution and not all projects will swap to 66. At present there are 2 or 3 options for where to source 66 kV cables, so a reasonable degree of competition. The industry has already seen the growth of competition of suppliers who can supply 66 kV cables, so reasonably good competition on price is healthy. Cable manufacturing so far has been all in all a positive experience, no concerns seen so far in the manufacture and qualification of 66 kV cables.

15.3.3 Market intelligence

Evidence	Source
• On 17/03/16 energy cable systems provider Prysmian Group has gained verification of its 66 kV cable system technology for offshore wind inter-array networks. The type testing of Prysmian's 66 kV cable system was carried out in accordance with CIGRE and IEC test protocols, as part of the Carbon Trust's Offshore Wind Accelerator	http://www.offshorewind.biz/2016/03/17/prysmians-

(OWA) programme. Prysmian has now type tested a 3-core, 66 kV EPR insulated “wet-design” cable system with aluminium conductor – copper is also available – and integrated optical element. The solution includes factory, field joints and plug-in terminations, using proprietary Click-Fit™ technology, and combines the use of EPR insulation. The qualification process was carried out in Prysmian laboratories in the UK and in Italy.	66kv-cable-system-ready-to-hit-offshore-wind-market/
• VBMS has been awarded a contract by EDF Energy Renewables to provide the subsea connection between the offshore turbines and the onshore grid for the Blyth offshore wind farm. The scope of work for VBMS includes the supply and installation of a total of approximately 14 kilometres of export and inter-array cable, the landfall pull ashore, and testing, terminations and commissioning services. VBMS will be using one or more of its cable-laying vessels and burial tools and has contracted Nexans as the supplier for the 66kV inter-array cables. Work is scheduled to commence in 2017. This will be the first project to use the new 66kV cable technology.	http://www.offshorewind.biz/2016/06/07/vbms-first-to-install-66kv-cables-at-blyth/
• In July 2016, JDR has unveiled a 66 kV inter-array cable that uses high-voltage technology to boost power transmission between offshore wind turbines. The cable has completed qualification and type testing program, including terminations and accessories, the UK subsea cable specialist said. The 66 kV technology has capabilities up to 72.5 kV and will contribute to the offshore industry´s cost reduction targets, JDR said.	http://renews.biz/103599/jdr-unveils-66kv-offering/
• On 28/09/16 Siemens has announced that it is offering a new 66 kV solution for offshore wind farms. The inter-array system can be ordered as an option with the Siemens offshore direct drive wind turbines and includes a transformer, a switchgear and a cable in between. Siemens explained that as more turbines can be put on each string due to the higher voltage, fewer strings are needed, and thus fewer array "feeder" cables. This provides additional advantages in logistics and installation. According to Siemens total savings in the cost of the park grid are estimated to reach up to 15%.	http://www.4coffshore.com/windfarms/siemens-presents-66kv-solution-nid4590.html

• The Glasgow-based UK Offshore Renewable Energy Catapult (OREC) has upgraded its UKAS-accredited high voltage (HV) electrical laboratory – providing enhanced testing capability unique in the UK – and paving the way for an industry shift from 33 kV to 66 kV for future offshore wind inter-array electrical systems.	http://www.scottishenergynews.com/66-kv-offshore-renewables-test-lab-upgrade-aims-to-cut-wind-farm-costs/

15.4 Additional comments

None for this indicator

15.5 Recommendations

None for this indicator

16 Improvement in array cable standards and specifications

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Array cables	Improvement in array cable standards and specifications

16.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ for 2016 because there has been publication of cross industry collaboration recently which are anticipated to aid cost reduction on near future projects. Collaborative groups such as CIGRE and others continue to progress work in this area. It is anticipated that further development of qualification and testing of array cables will continue, particularly as 66 kV array cable technology is deployed more widely.

Outlook:

A ‘high confidence’ was expressed by industry in the future outlook for progress in this indicator, suggesting a confidence that ongoing work to improve array cables standards and specifications is anticipated to continue and deliver benefit to the industry.

16.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	First project contracts with optimised cable specs and standards	Further projects contract using optimised array specs	Most projects contract using refined specs	All array cables optimally specified for the site and project conditions	All array cables optimally specified for the site and project conditions
On target	Joint industry project delivers	First project contracts with optimised cable specs and standards	Further projects contract using optimised array specs	Most projects contract using refined specs	All array cables optimally specified for the site and project conditions
Behind target	Joint industry collaboration underway to explore cable specs	Joint industry project delivers	First project contracts with optimised cable specs and standards	Further projects contract using optimised array specs	Most projects contract using refined specs
Missed target	No improvement	Joint industry collaboration underway to explore cable specs	Joint industry project delivers	First project contracts with optimised cable specs and standards	Further projects contract using optimised array specs

16.3 Evidence

16.3.1 Questionnaires

Category	Questionnaire response

Discuss any improvements made over the last year in the way that developers determine array cable specifications.	
[Installation]	Developers are recognizing the importance of undertaking up-front engineering on the cables, and recognizing the importance of correct vessel/contractor selection and its implications on the project success/efficiency. Flexibility of cable supply - such as long-length vs pre-cut vs turntable loaded vs reel/drums all have impacts on the overall working programme. Also developers are beginning to understand that the cable pull-in can be a major bottle neck if relying on small vessels which are not weather resistant.
[Developer]	There is no standard that is applicable offshore. But one is being written by the industry. Otherwise in-house know how to ensure challenging conventions yet remaining safe.
Explain whether you think further improvements are possible and detail any current/future industry projects that seek to support this.	
[Installation]	With next gen offshore wind being further from shore and in deeper water, the use of weather resistant vessels and permanent offshore located personnel is increasing. Sharing vessels across multiple packages (e.g. accommodation/construction support) can improve cost efficiency not just on the cable package. In terms of the physical installation - termination & testing remains a long duration task and might be improved through various means.
[Developer]	Carbon trust works, e.g. CBRA, free hanging cables, ratings.
Do you think that further significant evolution of array cable standards and specifications are likely in the next 3 years? If so please detail.	

[Developer]	First draft of new offshore cable standard. Perspective of various accessories will change as items are challenged.

16.3.2 Interview

Category	Interview response
[Developer]	It may be that some changes will occur as a result of increasing use of 66 kV, not too much comment in this area or knowledge of specific developments. Taking a risk on moving to 66 kV cable is easier on a less complex site.

16.3.3 Market intelligence

Evidence	Source
• In February 2016 the Carbon Trust published the new Application Guide for the Specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology. The guide explains how the pioneering probabilistic methodology can be applied to real offshore projects based on actual experience from an operational wind farm. It offers a standardised, repeatable and qualitative method to improve risk management of subsea cables for offshore wind farms. According to industry figures shared by specialist offshore underwriter, GCube over 80% of construction projects have resulted in a cable related incident, with over half of claims being attributed to incorrect installation and load out of cables.	https://www.carbontrust.com/resources/guides/renewable-energy-technologies/application-guide-for-the-specification-of-the-depth-lowering-using-

	the-cable-burial-risk-assessment-cbra-methodology/
• DNV GL has independently reviewed and approved the latest version of Tekmar Energy's patented TekLink cable protection system (CPS) and Bellmouth Accessories. Tekmar Energy, a specialist in CPS for the offshore wind industry, engaged with DNV GL to further establish its rigorous design and engineering standards adopted across its product offering.	http://nawindpower.com/tekmars-cable-protection-systems-receive-dnv-gl-approval

16.4 Additional comments

None for this indicator

16.5 Recommendations

None for this indicator

17 Extended (XL) monopiles and improved design standards

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Support structures	Extended (XL) monopiles and improved design standards

17.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	On target	↓	Medium confidence

Finding: Ahead of target

Marked as on target in 2016 because monopiles of around 8 m in diameter are currently being manufactured and installed, new design guidance has been delivered by industry collaborative projects and there is evidence to suggest that sufficient noise mitigation can be achieved. There is clear evidence that installation of 8m diameter piles of up to 1300 t in weight is possible. This indicator could not be assessed as 'ahead of target' for this year because there is limited evidence to suggest that noise mitigation or installation technologies have been demonstrated for piles of greater than 10 m in diameter.

Last year this indicator was scored as ahead of target noting the designs for large piles that have subsequently been manufactured and installed over the last 12 months. Another trend noted last year was the consideration that overall mass may become a greater constraint on the final ultimate size of feasible monopiles due to the limited availability and hence cost of installation vessels capable of installing foundations weighing over 1000 t.

There has been a continued expansion of the envelope of application of monopile foundations in the offshore wind industry, and for some time design, manufacturing and installation of ever larger monopiles in ever deeper waters has been an ongoing trend. Evidence this year suggests that while more projects are likely to deploy jacket and/or suction foundations, monopiles will remain the dominant foundation type for the medium term.

Outlook:

Evidence from engagement this year suggests that as well as the constraint of installation mass, piling noise is expected by the industry to be a limiting factor in the application of larger monopiles in future. However, as several competitors have invested significantly in production facilities for XL monopiles it is likely that strong competition will ensure the continued deployment of monopiles. Noise limits for installation processes vary across different regulatory regimes, but it is expected by most consultees that the permitted noise thresholds will steadily reduce over time. Some technology innovation is also evident, for example in vibro-piling techniques. Such technology could in future allow for lower noise installation and hence enable the installation of XXL diameter piles of 10 – 12m+. The outlook for monopile foundations remains positive.

A ‘medium confidence’ was expressed by the industry in the future outlook for this indicator. This reflects the fact that the envelope of monopile application is expected to continue to expand, but also that challenges remain in development of the piles and the supporting (installation) technology.

17.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	10 m monopiles can now be manufactured and installed Novel piling and noise mitigation	First project contracted using 10 m monopiles Novel piling and noise mitigation methods contracted	More projects contract 10 m monopiles Novel piling and noise mitigation methods contracted	50% plus of 6 MW projects use monopiles with a quarter of 8 MW projects. New design standards	50% plus of 6 MW projects use monopiles with a quarter of 8 MW projects (up to 12 m diameter). New

	demonstrated at 10m+ scale and associated design standards under development	for 10 m diameter piles on commercial project	for 10 m diameter piles on more than one commercial project	common practice Novel piling and noise mitigation methods contracted for 6 and 8 MW turbines commercially	design standards common practice Novel piling and noise mitigation methods contracted for 6 and 8 MW (12 m) turbines commercially
On target	First projects contract with 8 m diameter piles. New design standards being adopted on projects Novel piling and noise mitigation methods contracted for 8 m diameter piles on commercial project	10 m monopiles can now be manufactured and installed Novel piling and noise mitigation demonstrated at 10 m+ scale and associated design standards under development	First project contracted using 10 m monopiles Novel piling and noise mitigation methods contracted for 10 m diameter piles on commercial project	More projects contract 10 m monopiles Novel piling and noise mitigation methods contracted for 10 m diameter piles on more than one commercial project	50% plus of 6 MW projects use monopiles with a quarter of 8 MW projects. New design standards common practice Novel piling and noise mitigation methods contracted for 6 and 8 MW turbines commercially
Behind target	Successful trials of larger diameter monopiles. Additional FID on 7 m+ monopiles Novel piling and noise mitigation methods contracted for 6 MW, 7 m+ commercial project	First projects contract with 9 m diameter piles. New design standards being adopted on projects Novel piling and noise mitigation methods contracted for 8 m diameter	10 m monopiles can now be manufactured and installed Novel piling and noise mitigation demonstrated at 10 m+ scale and associated design standards under development	First project contracted using 10 m monopiles Novel piling and noise mitigation methods contracted for 10 m diameter piles on commercial project	More projects contract 10 m monopiles Novel piling and noise mitigation methods contracted for 10 m diameter piles on more than one commercial project

		piles on commercial project			
Missed target	No further FID on 7 m+ diameter monopiles Novel piling and noise mitigation methods demonstrated but no commercial contracts placed yet	No further FID on 8 m+ diameter monopiles Novel piling and noise mitigation methods contracted for 6 MW, 7 m+ commercial project	First projects contract with 9 m diameter piles. New design standards being adopted on projects Novel piling and noise mitigation methods contracted for 8-9 m diameter piles on commercial project	First projects contract with 10 m diameter piles. New design standards being adopted on projects Novel piling and noise mitigation demonstrated at 10 m+ scale and associated design standards under development	12 m monopiles can now be manufactured and installed Novel piling and noise mitigation methods contracted for 10 m diameter piles on commercial project

17.3 Evidence

17.3.1 Questionnaires

Category	Questionnaire response
How large in diameter do you think monopiles will become?	
[Foundation]	10 meters maximum.

Designer / Survey	10 m plus
[Installation]	Not my field
[Developer]	We are usually guided by the supply chain and they are developing capabilities for at least 10 m diameter at present.
[Developer]	Up to 12 m
What is the largest diameter monopiles that you have incorporated into a wind farm design to date? Please detail.	
[Foundation]	No input
Designer / Survey	8 m is the largest project we have seen so far
[Installation]	Not my field
[Developer]	7.5 m
[Developer]	6.3 m [PROJECT]
Are you considering using monopiles for 7 or 8MW turbines?	

[Foundation]	No
[Installation]	No
[Developer]	Yes
Are necessary piling and noise mitigation measures for large diameter monopiles available to you?	
[Foundation]	No
Designer / Survey	We don't offer noise mitigation but we can measure piling noise and we offer pile drilling as an alternative to hammering.
[Installation]	Not my field
[Developer]	yes at present, we have not investigated these for 10 m diameter piles to date
[Developer]	Yes
If so, which methods are you implementing?	
[Foundation]	No input

Designer / Survey	N/A
[Installation]	Not my field
[Developer]	We have tested vibropiling and implemented a number of noise mitigation methods for driving including shrouds and bubble curtains having led industry research projects in these areas
[Developer]	Double big bubble curtain but this is on jacket pin-piles at present.
What water depths do you see as being suitable for monopile foundations, do you expect this to increase in the next three years?	
[Foundation]	30 m maximum water depth
Designer / Survey	We do see water depth increasing with mono-pile foundations
[Installation]	Not my field
[Developer]	Assuming the use of the largest currently available WTGs and latest design methods we expect monopiles to be feasible in around 40 m water depths depending on ground conditions and wind/wave regime. The certainty of this is expected to increase over the next three years as R&D findings are demonstrated more widely.

[Developer]	Up to 40 m, could increase to ~45 m. Dependent on choice of WTG and environment
Finally, please describe any recent revisions in monopile design standards that have affected you.	
[Foundation]	No input
Designer / Survey	As previously mentioned we are developing some updated design methods based upon the use of cyclic data which in some cases can offer more cost effective foundations.
[Installation]	Not my field
[Developer]	The change in code from DNV OS J101 to ST 0126 may have an impact on our current and recently installed piles and is currently under review. New design methods such as those arising from the PISA programme are also of interest and their use investigated for future projects
[Developer]	n/a

17.3.2 Interview

Category	Interview response
How large in diameter do you think monopiles will become?	

[Designer]	From a consultancy perspective [Designer] could design larger Monopiles, the constraint is what is available in the market to fabricate and install such designs? Is it sufficient? For [PROJECT] 7.5 m diameter Monopiles of several hundred tonnes were installed which pushed the current boundaries of weight and size. The main constraint around utilisation of XL Monopiles is the cost associated with the large installation vessels, the size of available piling tools and the environmental impact of the piling noise.
[Developer]	Monopile installation noise is an issue, so piling noise could be a limiting factor for an increase in size of monopiles when looking into the future.
[Foundation]	Jackets have begun to look better and more cost effective for deeper waters but monopiles keep adapting and being considered for the deeper waters. The 40 m water depth appears to be the cut off point for monopiles, once you go over this jackets become more attractive. [Foundation] do not intend to go into the fabrication of very large monopiles for turbines. [Foundation] see other established more organisations fabricating 1300 t + monopiles and are focussing on jackets and TP's.
Is the interface between designer/fabricator/installer optimised?	
[Designer]	[Designer] believe this is very important to optimise in order to minimise costs of foundations. If there is not holistic approach, fabrication costs could be double.
Finally, please describe any recent revisions in monopile design standards that have affected you.	
[Designer]	For monopile design in general, [Designer] believe the industry needs to move towards standardisation of design – switchgear, boat landings etc. – and a commodity based industry.

[Developer]	Optimised monopoles Optimised TPs

17.3.3 Market intelligence

Evidence	Source
• At the EWEA Conference 2015 (17-20 November 2015), DTU presented an innovative large diameter monopile (XL monopile) being conceptually designed to support the DTU 10 MW wind turbine at water depth of 50 m. The design of this large diameter monopile at 50 m water depth was carried out by jointly designing the wind turbine tower and monopile considering manufacturing constraints and understanding soil plastification or the inability of the soil to support dynamic loading beyond a certain deflection of the pile. Further studies are being made now to investigate if proper consideration of soil resistance to yaw loads can aid in the structural design of the monopile in addition to the influence of soil skin friction.	https://stateofgreen.com/files/download/2220
• On 02/02/16 an article published in REcharge underlined that there are developers that support XL monopiles. For example, some over seven metres in diameter and weighing up to 1,300 tonnes, have been selected for landmark mid-water-depth projects such as the 600 MW Gemini development off the Netherlands and the 400 MW Rampion and 336 MW Galloper wind farms off Britain, pushing back the boundaries for monopiles to water depths closer to 40 m, well beyond the previous thresholds of the technology. MHI Vestas after having manufactured the first serially produced 8 MW V164 turbines for projects such as UK's Burbo Bank Extension and Denmark's Horns Rev 3, is also on record as backing the trend towards using XL monopiles "to the biggest possible extent", both for reasons of cost and the security of a mature supply chain. Lars Hammershøj, co-founder of consultancy K2 Management, told Recharge that there is still a lot more be done with monopiles, for specific projects pointing to the 400 MW Veja Mate project off Germany, which is due to use XL monopiles topped by 6 MW wind turbines in 40 m of water.	http://www.offshorewindindustry.com/news/eew-produced-worlds-heaviest-monopile

• In March 2016, the heaviest monopile for the offshore wind branch ever produced has left the production site of EEW Special Pipe Constructions GmbH (link is external) in Rostock. It is designed to be the foundation for a 6 MW turbine at Veja Mate wind farm. This monopile weighs a total of 1302.5 t, its diameter is 7.8 m, and it is 82.2 m long – a record in the world of offshore wind energy. The next step will be the coating of this XXL monopile.	http://webcache.googleusercontent.com/search?q=cache:f6LLq3ewE5YJ:www.rechargenews.com/incoming/1422134/in-depth-the-monopiles-comeback-is-shaking-the-foundations+&cd=1&hl=en&ct=clnk&gl=uk
• On 19/04/16 Atkins' offshore renewables team have marked the installation of the first monopile and transition piece at Statoil's Dudgeon offshore wind farm, achieving a major milestone in the project, which will see 67 wind turbine foundations and a 1400 t offshore substation installed in the course of the year. The use of 6 MW turbines and a wide range of different ground conditions across the site presented Atkins' multidisciplinary team with a number of challenges to create the most efficient design solution. The final design pushed the boundaries of existing monopile foundation design codes, and are the largest diameter monopiles currently in use in an offshore wind farm.	http://www.atkinsglobal.co.uk/en-GB/media-centre/news-releases/2016/apr/2016-04-19
• On 01/08/16 Dutch fabrication group SIF, which started out in 1948 as a metal working outfit (Silemetal) for large vessels, is now investing some $70.9 million (€64 million) in a new facility at Rotterdam's Maasvlakte 2 to increase capacity – to 300,000 t/year, or four XL monopiles (XL being over 7 m diameter) a week. The monopile diameter size it can produce up to will increase to 11 m with monopile length to 120 m and weight to 2,000 tonnes. In the	http://www.oedigital.com/production/item/13190-

near future, however, Sif believes that it is sufficient to make foundations with 9 m diameters which are 100 m long and weigh 1,500 tonnes.	increasing-capacity
• A press release from Tube Duesseldorf International Tube and Pipe Trade Fair 2016 states that other manufacturers, apart from SIF, are now opting for the production of such XL, XXL or mega monopiles. EEW Special Pipe Constructions GmbH in Rostock produces large, longitudinally welded pipes, with thick walls, up to 10 m in diameter, up to 120 m in length and up to 1,500 tonnes in weight. This is currently the most cost-effective foundation structure for offshore wind farms with turbines in the 5-to-8-MW class, at a depth of up to 40 m. According to the manufacturer, this allows savings of up to 30% on foundations compared with a jacket design. Such savings are apparently substantial, as foundations account for 20 to 25% of the total cost in an offshore project.	http://www.tube-tradefair.com/cipp/md_wiretube/custom/pub/content,oid,2368420/lang,2/ticket,g_u_e_s_t/~/FA_07_Monopiles_%E2%80%93_gigantic_pipes_for_offshore_wind_farms.html
• On 14/07/16 German Federal Ministry of Economic Affairs and Energy (BMWi) announced that is funding a new research project launched by Ramboll, Fraunhofer IWES and Leibnitz University Hannover to reduce the levelised cost of energy (LCOE) by improving the design of large monopiles. The TANDEM project (Towards an Advanced Design of Large Monopiles) aims to reduce design risks and cost of offshore wind turbine foundations. Over a period of three years, the project partners will be revisiting hydrodynamic and geotechnical approaches with the scope to further improve current design methodologies for large diameter monopiles.	http://www.offshorewind.biz/2016/07/14/new-rd-project-to-reduce-lcoe-by-enhancing-large-monopile-design/

17.4 Additional comments

None for this indicator

17.5 Recommendations

None for this indicator

18 Novel monopile design concepts

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Support structures	Novel monopile design concepts

18.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
N/A	On target	N/A	Medium confidence

Finding: On target

This indicator has been marked as ‘on target‘ in 2016. There is evidence that some projects are considering radically different monopile foundation designs, including the concept of ‘hammering on the flange’ to permit the deployment of turbines onto monopiles with no transition piece. Such technology has been demonstrated at one nearshore site in benign conditions, and significant potential for steel mass reduction and installation time savings exist if radical concepts like these could rationalise monopile foundation designs.

This is a new indicator for 2016 and as such no score exists for comparison from previous studies.

Alongside the removal of the transition piece from monopile foundation designs there were other novel concepts suggested during engagement around the design of secondary items such as working decks, ladders and boat landings. It is suggested from engagement conducted for CRMF 2016 that whilst there is a convergence on some general themes these relatively similar items are commonly designed bespoke for a single project, customer or application.

Outlook:

In future there remains opportunity for cost reduction through radical layout design concepts, standardisation and potentially something approaching a commodity market in second and third level fabricated components. A move towards some increasingly standardised elements looks likely, with significant potential for cost reduction remaining in novel foundation design concepts.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator. It is clear that significant potential remains, with some uncertainty how much is likely to change by 2020.

18.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	At least one project demonstrates a radically different monopile foundation design (e.g. no transition piece) and has proven a resulting cost saving.	At least two project demonstrates a radically different monopile foundation design (e.g. no transition piece).	Several sites have demonstrated a radically different monopile foundation design (e.g. no transition piece).	The design and installation of monopile foundations has been optimised, with suitable sites achieving significant savings of steel mass through the application of radical designs.	The design and installation of monopile foundations has been optimised, with suitable sites achieving significant savings of steel mass through the application of radical designs. Proven savings are achieved in steel mass, fabrication, design and installation costs.

On target	At least one project demonstrates a radically different monopile foundation design (e.g. no transition piece).	At least one project demonstrates a radically different monopile foundation design (e.g. no transition piece).	At least two project demonstrates a radically different monopile foundation design (e.g. no transition piece).	Several sites have demonstrated a radically different monopile foundation design (e.g. no transition piece)	The design and installation of monopile foundations has been optimised, with suitable sites achieving significant savings of steel mass through the application of radical designs.
Behind target	Evidence of novel monopile foundation designs being considered at concept design.	Evidence of novel monopile foundation designs being considered at concept design.	Novel monopiles have been selected at concept design stage but are slow to progress to commercial projects.	One project demonstrates a radically different monopile foundation design (e.g. no transition piece).	Most suitable sites can demonstrated optimised novel monopile foundation designs, with suitable sites achieving significant savings of steel mass through the application of radical designs.
Missed target	Difficulties experienced in revising designs.	No progress.	Limited evidence of novel monopile foundation designs being considered at concept design.	Novel monopiles have been selected at concept design stage but are slow to progress to commercial projects.	One project demonstrates a radically different monopile foundation design (e.g. no transition piece).

18.3 Evidence

18.3.1 Questionnaires

Category	Questionnaire response
Have you been involved with any research or projects seeking to adopt novel monopile designs (e.g. removing transition piece from design) if so please provide details.	
[WTG OEM]	Not on monopile designs. Already the lowest cost and most efficient turbine platform
[Foundation]	No input
Designer / Survey	No
[WTG OEM]	Confidentiality considerations
[Installation]	not applicable
[Developer]	We are active in a number of research projects related to pile optimisation. These include further design refinements such as involvement in the R&D programmes PISA, SLIC, and projects at a less mature stage such as review of the D/T ratio for pile design and novel designs.

[Developer]	No

18.3.2 Interview

Category	Interview response
[Designer]	In terms of novel monopile designs, [Designer] are aware of increased use of Monopiles without transition pieces in China. For this approach it is important to understand and address the fatigue issues during installation.
[Developer]	Not much to say

18.3.3 Market intelligence

Evidence	Source
• On 27/07/2016 Ramboll mentioned in a press release that the installation of the last of 150 wind turbines at the Gemini Offshore Wind Park on 23 August 2016 and the official start of operation of Luchterduinen on 21 September 2015 have added new milestones to the records of Ramboll in offshore wind and to the excellent cooperation between Van Oord and Ramboll. Regarding the design of the monopile foundation structures, Gemini (150 x SWT-4.0-130, water depth up to 37 m) and Luchterduinen (42 x V112-3.0 MW MHI Vestas, water depth up to 24 m) are not just another two projects. What makes Luchterduinen so special is that the monopile does not have a transition piece as the tower is mounted directly on the one-piece monopile. All secondary structures (boat landing, access system, platform etc.) are attached to support points, which have been specially designed to withstand the	http://www.ramboll.com/media/rgr/luchterduinen-and-gemini-two-success-stories-in-offshore-wind

accelerations during driving of the monopiles into the sea bed. This innovative design has resulted in a considerable reduction of costs as well as considerable reductions in the offshore installation time down to 12-14 hours per monopile.	

18.4 Additional comments

None for this indicator

18.5 Recommendations

None for this indicator

19 Optimised Jacket design and manufacture

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Support structures	Optimised Jacket design and manufacture

19.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016, there is evidence of increasing commitment to jacket foundations for projects, with bespoke production facilities open and an increasing pipeline for jacket design, fabrication and installation. Near term projects including Wikinger, Beatrice, East Anglia One and Hornsea project one. There was significant discussion during engagement in the optimisation of a balance between bespoke design, design for manufacture and automated processes in the fabrication of jackets.

Last year this indicator was assessed as ‘behind target’ noting that while manufacturing facilities existed there had not yet been sufficient demand to fully occupy new facilities, with at that stage only a visibility of pipeline projects. Many of these projects have since progressed.

It is anticipated that demand for jackets will in the near future continue to gradually increase, based on the visible pipeline of projects likely to adopt jackets. Manufacturing locations for jackets continue to be spread across Western Europe, with projects tending to split the supply

of jackets across several fabricators, evidence suggests that in future and in order to meet potential peaks of demand there may be some jackets manufactured further afield. It is not certain that the 2020 vision of optimised manufacturing of standardised elements will be achieved by all facilities by 2020.

Outlook:

There remains potential for significant improvement in future, particularly around standardisation and automation of manufacture. There is a challenge for the supply chain in managing the potential variance in demand for jackets as projects each pas through fabrication stage. Engagement suggests that without a stable pipeline jacket manufacturers struggle to justify significant upfront investment in capabilities. There may also be some uncertainty introduced in the level of future demand by projects which decide to revert their foundation selection to monopiles. Finally, an interesting comparison may be seen in coming years as projects such as Hornsea project one install a mixture of monopiles and jackets for the same site, allowing objective technical and commercial comparison in relatively similar applications.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, although note that the score was close to achieving ‘high confidence’. There was evidence of optimism in the near to medium term future cost reduction potential in jacket design and manufacture.

19.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	30% of jackets make full use of improved design methodologies and standards, competing with monopiles at 35 m	50% of jackets make full use of improved design methodologies and standards	70% of jackets make full use of improved design methodologies and standards	Almost all jackets use standard elements, including new design standard	Almost all jackets use standard elements, including new design standard

	with 6 MW wind turbines				
On target	Improvements in design and standards continue. Second advanced jacket manufacturing facility is open	30% of jackets make full use of improved design methodologies and standards, competing with monopiles at 35 m with 6 MW wind turbines	50% of jackets make full use of improved design methodologies and standards, competing with monopiles at 35 m	70% of jackets make full use of improved design methodologies and standards, competing with monopiles at 30 m	Almost all jackets use standard elements, including new design standard, competing with monopiles at 35 m
Behind target	Improvements in design and standards continue. R&D projects report on p-y interactions	Improvements in design and standards continue. Second advanced jacket manufacturing facility is open	30% of jackets make full use of improved design methodologies and standards, competing with monopiles at 35 m with 6 MW wind turbines	50% of jackets make full use of improved design methodologies and standards	70% of jackets make full use of improved design methodologies and standards
Missed target	New jacket manufacturing facility operational with refinements in design using standard pipes, nodes and component lengths being used by market. Additional advanced jacket	Improvements in design and standards continue. R&D projects report on p-y interactions	Improvements in design and standards continue. Second advanced jacket manufacturing facility is open	30% of jackets make full use of improved design methodologies and standards, competing with monopiles at 35m with 6MW wind turbines	50% of jackets make full use of improved design methodologies and standards

	facility reaches FID. Studies underway to review p-y interaction				

19.3 Evidence

19.3.1 Questionnaires

Category	Questionnaire response
Are you aware of any purpose-built jacket manufacturing facilities reaching (or about to reach) financial close (other than Bladt at Lindo and Bilfinger at Szczecin)?	
[Foundation]	Yes - confidential information.
Designer / Survey	No
[Installation]	not applicable
[Developer]	No
[Developer]	No

Describe the results of any studies looking at p-y interaction or improved methodologies for jacket design, manufacture or fabrication that you have been involved with.	
Designer / Survey	As previously mentioned we are doing our own revision to pile design methods. We also are sponsoring a PhD student at Oxford.
[Installation]	not applicable
[Developer]	GOAL https://ore.catapult.org.uk/our-knowledge-areas/foundations-substructures/foundations-substructures-projects/goal/
[Developer]	About to join JaCo project with Offshore Wind Accelerator to optimise fatigue design of jackets nodes
At what water depths would you consider jackets competitive against monopiles?	
[Foundation]	30 m
Designer / Survey	No comment
[Installation]	My personal, private view is that jackets can be competitive with monopoles in all water depths.
[Developer]	This is highly dependent on site conditions and market conditions. The most recent experience where the comparison was truly tested (i.e. full tender prices) within our projects showed jackets remained more expensive than monopiles by a small

	margin (circa 10%) at around the water depth where monopiles were no longer feasible due to site constraints (just under 40 m in this case).
[Developer]	35 m+

19.3.2 Interview

Category	Interview response
[Foundation]	When considering a jacket foundation solution on paper, particularly from an engineering point of view it is a technically very attractive option. The key benefit is the robustness of the system from a design and structural point of view. However, there are also many downside of a jacket foundation system which must be considered. The monopile industry has developed rapidly, a lot of people invested into the supply chain and a lot of capacity has been built. There are now at least 5 – 6 very established players manufacturing monopiles in Europe. Relatively low risk to carry on with business as usual and single sourcing is safe and effective and cheap. For jackets however companies tried to enter the market to supply, but found the peaks and troughs of demand have led to high profile exits industry or bankruptcy. [COMPANY] have been the most successful in delivering jackets, but they see big swings from solid bottom line to decline in profits, which could be associated with the stability of pipeline of projects. Jacket manufacturing from a supply chain perspective is a massive challenge, it requires at least 3 yards for a decent size (e.g. [PROJECT]) project and so running a project like this spread across Europe is a real challenge for the developer and supply chain alike.

	The whole premise for cost out for jackets is based on standardised manufacturing and design. There is a need for some element of standardisation in design, but none of the developers are willing to work together and really design the most optimal jacket structure for the supply chain perspective. There may be potential for 30% cost reduction in jackets if design and assembly correctly but do not expect sufficient collaboration on this in next 5 years for such cost savings to materialise, as no actor is big enough/motivated to collaborate to make it happen. A suction foundation manufacturer [Foundation] have understandably run a lot of comparisons of other types to their own foundation. From these exercised there are some pretty strong indications of what a jacket costs from a procurement point of view. For example, 3.5m EUR per jacket is a number that based on public statements could be quoted. However, once procurement is completed and from a project perspective there will almost always be a cost overrun as designs are not fully ready when fabrication has to start. So €3.5m which may be used at the tendering/design/procurement phase may commonly end up costing a project 20 – 30% more, which tends to appear as a contingency and may not be reflected in the capex of the foundation. Reflecting this to mono-bucket, 2/3 of weight of the structure is a monopile, so chances for cost overruns are more similar to a monopile (e.g. much lower than for jackets) and using a suction foundation avoids the risk of a jacket supply bottleneck associated with the small number of players and the fluctuating pipeline of projects. [Foundation] have so far put quite a lot of effort into (from an engineering perspective) standardising the design of the monobucket. Perhaps there is still more to do in optimising the design for fabrication point of view. Expect that they are now on same level for fabrication is the same as s monopile, but potential to unlock more cost reduction in production later is greater than what remains in optimised monopiles for fabrication cost reduction. Suction jacket is cheaper than comparable jacket, but still does not look like a combination of the most cost efficient components.

	One comment or further question is one which could be posed to a jacket manufacturer, do they believe that they have certainty in designs, and at what stage? Does this lead to cost overruns and will it change in future?
[Designer]	The future market for jackets is likely to be linked to the development of floating foundations, the ability to manufacture and install XXL monopiles and the ability to handle the higher loads produced by the larger turbines.. If floating develops and becomes price competitive, this may displace jackets from the 'deep water' market. However, in international regions with typhoons and high seismic behaviour and where large turbines produce large loads there is likely to still be a market for jackets.
[Foundation]	Jackets are beneficial in that they can use 2/3 the amount of steel as a monopole and a stiffer structure to allowing overall structure optimisation with resulting cost savings (e.g. reduced weight in the tower). [Foundation] is quite confident that jackets will reduce costs and are progressing jacket fabrication for a particular offshore project – they expect to soon be producing a jacket a week for this project. [Foundation] hopes to be able to show that by working with a standardised jacket design that lends itself to being easily fabricated, can contribute to cost reduction, and up to a 30% cost reduction in the primary steel jacket.
[Foundation]	Monopiles are fairly mature technology and there is less scope for optimisation, however jackets are fairly new and the industry could work to standardise on one design which could get the costs down quicker helping to realise the weight benefits of jackets (much less steel) over monopiles. [Foundation] have been working for 2 years to try to chorale industry towards a standardised design. [COMPANY] have hosted an event (Danish jacket group) which is open to anyone and is looking at possible standard jacket designs for the industry. [PROJECT] aside, there are many 3 legged jacket structures being used on projects so the industry might be moving itself naturally towards that as a standardised design.

[Foundation]	[Foundation] is keen to explore final assembly of jackets on UK quay side. This may be possible through standard designs where nodes and pipes could be easily prepared and transported to key sides for final assembly, which introduces local content in the supply chain, develops local skills and provides a competitive foundation for the customer. A design which supports easy assembly would be needed.

19.3.3 Market intelligence

Evidence	Source
• On 25/05/16 Atkins announced that has been appointed by Seaway Heavy Lifting (SHL) to carry out the detailed design of the jacket substructure and foundations for the 588 MW Beatrice Offshore Windfarm Limited (BOWL) development in the outer Moray Firth, UK, as part of SHL's EPCI contract with developer BOWL (a partnership of SSE Renewables, SDIC Power, and Copenhagen Infrastructure Partners). 84 jacket substructures and associated foundations for the Siemens 7 MW turbine will be installed at varying water depths up to 55 m which represents the deepest jacket substructures in use for an offshore wind farm anywhere in the world. Andy Thompson, Atkins' offshore wind deliver director, said: "...Drawing on years of jacket design experience in oil and gas, and an industry leading offshore wind team, we're designing the first mass-produced deep water jacket substructure for an offshore wind farm. The evolution of the jacket substructure in this way is enabling savings on steel, fabrication and installation costs as we are developing a lighter, simpler and highly standardised substructure."	http://www.atkinsglobal.co.uk/en-GB/media-centre/news-releases/2016/may/2016-05-25
• Keystone Engineering (Keystone) was retained to design jacket-type substructures for the five, 6 MW wind turbine generators. As an innovative solution for the design of the deep-water wind turbine support structures, the Keystone team adapted the steel jacket foundation design typically used in the oil and gas industry. Bentley SACS enabled Keystone to design the composite construction and complex nodal geometry of the jacket	http://www.pennenergy.com/articles/pennenergy/2016/06/keystone-engineering-designs-

substructures, delivering an alternative to the typical monopile concrete foundations that are limited to offshore wind farms located in more shallow water depths. Keystone leveraged the technology developed for the offshore oil and gas industry to meet the complex design criteria for the jacket foundations. The iterative process optimized the jacket design and reduced the amount of steel needed for the substructure, while still ensuring a design life of more than 20 years. As a result, the Block Island Wind Farm jackets are 15 percent lighter than a previous design used for the same type of wind turbine in the North Sea. The optimized design also reduced installation costs by more than 20 percent compared to traditional monopile construction and can survive hurricane-force winds.	first-commercial-offshore-wind-farm-in-the-u-s.html

19.4 Additional comments

None for this indicator

19.5 Recommendations

None for this indicator

20 Suction bucket

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Support structures	Suction bucket

20.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016. Significant test and demonstration at reduced and at full scale of suction foundations has been conducted in recent years. Hornsea project one has announced plans to deploy suction foundations and the EOWDC has already conducted trial installations of scale suction foundations ahead of installation at full scale in the near future.

Last year this indicator was also assessed as ‘on target’ noting the successful completion of trial installations, including those supporting offshore met masts.

There remains good potential for the application of suction foundations at applicable sites. Evidence collected through engagement suggests that technical aspects of this approach are now reasonably mature, with significant opportunity to standardise and industrialise the design and fabrication process to achieve cost reductions comparable to those which have been achieved in XL monopiles in recent years.

Outlook:

It is likely that a number of sites, including some in the UK will see commercial deployment of suction foundations supporting turbines in the near future. Particular comment from the supply chain suggested that cost reduction could be enabled through knowledge sharing programmes in suction foundations, but that they felt this looked unlikely under the competitive CfD regime. It would appear safe to assume a gradual increase in the deployment of suction foundations at suitable sites in the coming years, and it is possible that even with designs which may not be fully technically optimised some cost reduction will be achieved by the deployment of suction foundations. Suction foundations may also find application in broadening the envelope of viable turbine locations at suitable sites, by complimenting the capabilities of traditional monopile or jacket foundations. There may be some challenges in deployment from traditional jack up installation vessels, as such installation methodologies are anticipated to mature in coming years.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator. Suction buckets are likely to see some deployment ahead of 2020, but the commercial competitiveness of the technology may require significant demonstration to enable wider uptake.

20.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Suction buckets competitive at certain sites	Suction buckets competitive at certain sites, taking	First suction bucket project operational. Suction buckets competitive at certain sites picking up at least a second order	Suction buckets dominant foundation type	Suction buckets dominant foundation type (i.e. most market share)
On target	First commercial scale project in EU contracts using technology	Suction buckets competitive at certain sites	Suction buckets competitive at certain sites, taking market share	First suction bucket project operational. Suction buckets competitive at	First suction bucket project operational. Suction buckets competitive at

				certain sites picking up at least a second order	certain sites picking up at least a second order
Behind target	One demo operational	First commercial scale project contracts using technology	Suction buckets competitive at certain sites	Suction buckets competitive at certain sites, taking	Suction buckets competitive at certain sites, taking
Missed target	One demo installed	One demo in place	First commercial scale project contracts using technology	Suction buckets competitive at certain sites	Suction buckets competitive at certain sites, taking

20.3 Evidence

20.3.1 Questionnaires

Category	Questionnaire response
Are any of your wind farms suitable for suction bucket foundations?	
[Foundation]	No input
Designer / Survey	We are working with developers on several sites to consider the suction pile alternative. Several sites probably do have suitable soils.

[Installation]	Don't have any wind farm
[Developer]	Yes
Explain whether you are considering the use of suction buckets in your FEED study and the rationale for or against.	
[Foundation]	No input
Designer / Survey	Potential cost saving on installation, decommissioning is potentially easier, not sure about cost comparison with other foundation types.
[Installation]	not applicable
[Developer]	Yes. No site investigated in the detail within the last 3 years has merited detailed consideration of suction buckets due to soil conditions being favourable for relatively small monopiles.
When do you expect the first commercial scale project will contract suction bucket foundations?	
[Foundation]	No input
Designer / Survey	2017

[Installation]	It's happening right now on [PROJECT] - isn't it?
[Developer]	Yes. No site investigated in the detail within the last 3 years has merited detailed consideration of suction buckets due to soil conditions being favourable for relatively small monopiles.

20.3.2 Interview

Category	Interview response
Are any of your wind farms suitable for suction bucket foundations?	
[Developer]	Suction Bucket Jackets (see press release)
Explain whether you are considering the use of suction buckets in your FEED study and the rationale for or against.	
[Installation]	Installation of jacket designs incorporating suction buckets is a big challenge to find the optimised combination of vessel choice/design, crane choice/weight and stand-off distance to make those installations happen smoothly. The challenge is whether you do your suction bucket jacket design first and specification before you specify the requirements of the vessel. The optimum situation would be to do them in iteration with each other, but if you do so you need to ensure the required vessel will be available for that jacket design – it is quite a complex process.
[Installation]	People are currently considering suction bucket jacket designs for projects in the very near future. It is unclear what is driving the decision to select suction bucket jackets. The choice of suction bucket jackets presents an issue for installation

	companies like [Installation] where you have deep penetration combined with suction bucket technology. Here you will have issue when the spud can gets pushed down into the soft ground and back filled over the top. Problems are introduced when the jacket uses its jetting system as part of this process in the vicinity of a suction bucket.
[Foundation]	First of all the [Foundation] technology concept is based on a monopile design, from the seabed up very similar but has a different seabed interaction or interface. [Foundation] have participated in a number of joint industry projects, with academics and PhDs etc. looking into optimisation of foundation design and suction buckets in particular. In terms of technology evolution, the driving out of costs from monopiles has already been squeezed quite a lot. Any remaining cost reduction in monopiles is unlikely to come from a reduction in fabrication cost as this is already a rather highly industrialised and highly competitive process and industry, rather any remaining improvements could be expected to arrive as result of further technical improvements and optimisation of design and design standards. In looking to the future the monopile industry looks likely to continue into 40 m of water with ever larger turbines, there does not seem to be a limit to the technical feasibility of monopiles getting ever larger, and the march to XL and beyond seems to continue. Perhaps some reason is that a lot of people have invested and made efforts to continue to stay competitive in monopiles, and as such now see their fate being intrinsically linked to the continued application of monopiles. Suction foundations are one technology which can give significant cost out to a developer by using a relatively low risk but still new technology. A developer must balance the technology risk and the viability and overall cost of a project.
[Foundation]	Installation of suction buckets is fast and proven and does not require as much equipment as other foundations. [Foundation] installed their system first in 2002, a small turbine shallow water, in 2009 they did a met mast [PROJECT]. 2013 did 2 installations at met mast.

	Also delivered a joint industry a trial installation (29x) in 24 days at a variety of future sites; [PROJECT], [PROJECT] and xx using the same 2 foundations. These trials saw each of the foundations installed and decommissioned repeatedly and in a rapid turnaround. Developers saw this as a great opportunity to learn and set a great record for how quickly suction foundations can be installed and decommissioned. In terms of practicalities when installing suction foundations, there is a requirement for a lifting yoke and suction pump unit and control containers to monitor installation. When looking at a comparable foundation vessel spread there is a requirement for more equipment, which are unnecessary when doing a suction installation, this equipment can be expensive and comes with risk. There has really been an improvement in speed and installation certainty of monopiles, which has moved quite fast in last couple of years.
[Designer]	[Designer] have advised clients on when and when not to use suction bucket foundations. The primary reason not to use suction buckets is geotechnical; you have to have the right geo-site and soil conditions. The main reason to have suction buckets is environmental; they reduce noise and ground disruption during installation.
When do you expect the first commercial scale project will contract suction bucket foundations?	
[Foundation]	This technology is still relatively new in offshore wind, however in oil and gas there have been over 2000 installations, giving a vast pool of experience to draw on, albeit accepting that these are from other applications. As a provider of suction bucket foundations, the journey of optimisation has only just begun. It has been proven that the technology is feasible and can work, but there is a lot to do in industrialisation of process, particularly in fabrication. The optimisation of design standards is going to impact the supply chain about how much steel is in the foundation. However although there has been a lot done to continue to move things forward there is a recognition that eventually the ever deeper application of monopiles will have to reach and end.

	By incorporating a suction bucket into the base of a monopile these can help to offer a solution that will further extend the life of this type of technology. In 30 m water the Suction bucket is 25% lighter than the monopile equivalent - a big part of this saving does not need a transition piece. Given the simple installation process of the Mono Bucket, the associated cost is easily 30-40% below the pile-driven equivalent. The other driver is amount of time required for penetration and offshore installation. So it may offer some technical advantages, accepting that a well optimised monopile is a highly industrialised proposition. Once thinking about 40 m of water the differences become starker and [Foundation] expects that monopiles will struggle to remain competitive against other technologies, such as suction buckets. First fully commercial application to use suction technology is expected to be [PROJECT], which will see some use of suction bucket jackets. The [Foundation] monopile topped suction bucket system has been trialled over a variety of sites. The first suction bucket monopile deployment will be a small project, which will be [LOCATION], which is expected to be in the water by 2018. [Foundation] also have an EU demo site expected to go ahead in 2019 – this will be a large turbine in deep water.
[Foundation]	[Developer] is considering the use of suction buckets for jackets and [PROJECT] is also using suction buckets. The main benefits are thought to be environmental. Recycling and removing the materials are a consideration and the reduction in piling noise during installation. Suspect there is less steel used in suction buckets than traditional piles, depending on the seabed conditions.

20.3.3 Market intelligence

Evidence	Source
• On 04/02/16 Dong Energy announced that one-third of the 171 Siemens 7 MW turbines at its 1.2 GW Hornsea 1 offshore wind farm will sit on suction-bucket jacket foundations.	http://www.rechargenews.com/wind/1423136/dong-to-deploy-suction-bucket-jacket-foundations-at-12gw-hornsea-1
• Sembmarine SLP has upended a 954 tonne substation jacket for the 402 MW Dudgeon offshore wind farm off the Norfolk coast. The Lowestoft engineering outfit is working with Siemens Transmission and Distribution Ltd (STDL) on the contract, while SPT Offshore fabricated the suction pile substation foundation.	http://renews.biz/101904/slp-upends-dudgeon-jacket/
• On 01/07/16 Norwegian Geotechnical Institute (NGI), an international center for geoscience research and consulting, and DONG Energy Wind Power signed a contract for the installation of 20 offshore wind turbine bucket foundations, called suction bucket jackets. The turbines will be placed at the offshore wind farm Borkum Riffgrund 2 in the German sector of the North Sea, located 54 km off the coast of Lower Saxony, next to Borkum Riffgrund 1.	http://www.oedigital.com/energy/item/12895-dong-ngi-install-suction-anchor-at-borkum-riffgrund-2
• On 29/09/16 Vattenfall, the Swedish state owned renewables company, has secured an order for 11 of the world's most powerful turbines for the European offshore wind deployment centre (EOWDC), also known as Aberdeen offshore windfarm. The turbines will be provided by MHI Vestas, the Danish engineering firm and "..will be paired with game-changing suction bucket foundations, representing an industry first", Adam Ezzamel, project director for the EOWDC at Vattenfall UK, said. Earlier in July 2016, Royal Boskalis Westminster N.V.	https://www.commonspace.scot/articles/9488/danish-and-swedish-companies-pour-more-

(Boskalis) has been awarded the Offshore Balance of Plant contract by Vattenfall to provide all offshore elements of the wind farm, with the exception of the wind turbine supply. The contract carries a value for Boskalis of well in excess of EUR 100 million. The scope of the activities for Boskalis includes, among others, the design, procurement, fabrication, supply, transportation and installation of eleven suction bucket jacket foundations and scour protection. The use of suction bucket jacket foundations in conjunction with the large wind turbines and the use of high capacity 66 kV power cables makes this project unique.	investment-aberdeen-wind-power-research http://www.marinelink.com/news/boskalis-aberdeen412904
• A revolutionary project in fresh water, known as Icebreaker project, in Lake Erie is set for completion by the fall of 2018 experimenting with a new means of mounting 500 foot tall wind turbines to Erie's lakebed, just 10 miles off the coast of Cleveland. Instead of drilling the turbine's foundation directly into seafloor bedrock, a massive steel drum, known as a Mono Bucket, establishes a suction cup-like grip on the lake's floor. The drums, which take just 12 hours to install, are less likely to disturb the environment than traditional "pile-driving" foundations, which are prone to releasing pollution and sediment trapped in deeper waters.	https://psmag.com/americas-first-offshore-wind-farm-is-almost-here-4ce07045abbd#.gmujl5gim

20.4 Additional comments

None for this indicator

20.5 Recommendations

None for this indicator

21 GBS support structures

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Balance of plant	Support structures	GBS support structures

21.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
N/A	Behind target	N/A	▪ Low confidence

Finding: Behind target

Marked as behind target for 2016 as there has yet to be a successful deployment of a float and submerge gravity foundation supporting a contemporary turbine and projects to date have delivered test and demonstration only, such as met masts. The Blyth Offshore Demonstrator project is currently fabricating floating gravity foundations for 5 MHI Vestas V164 turbines, but these will not be installed in time to enable this indicator to be assessed as ‘on target’ for this year.

This indicator is a consolidation (due to limited levels of activity) of two indicators related to GBS from previous years: “Lifted GBS with turbine pre-installed”, and “Floating GBS”. These indicators were assessed as ‘behind target’ and ‘missed target’ respectively in CRMF 2015.

The progress in moving the consolidated indicator upwards to ‘behind target’ and close to achieving ‘on target’ has been largely driven by the work of EDF at the Blyth site.

A key consideration when contemplating float out GBS foundations is the requirement for sufficient space at the fabrication port(s), which could significantly challenge projects considering the use of this technology in future.

Outlook:

In the near future there will be a small number of projects, expected to be at a demonstration scale, which will use gravity foundations. Looking further there are some European markets where for reasons of ground conditions and a political commitment to local content it is likely that gravity foundations will be deployed at scale. It may not be that gravity foundations are selected by developers as a cost reduction, rather that they will develop as a niche product which can be used to make certain sites viable.

A 'low confidence' was expressed by industry, supporting the view that this technology is not anticipated to see widespread adoption in future, and certainly not by 2020.

21.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	GBS foundations are available to market. First commercial project contracts using some form of GBS.	First commercial project or small share of market contracts using GBS.	At least two projects contracts using GBS.	At least two projects contracts using GBS. GBS competitive with alternatives on certain site types.	Several projects contract GBS with cost reduction demonstrated through competition in the supply chain.
On target	First successful trial or demonstration of GBS being used for a turbine.	GBS foundations are available to market. First commercial project contracts using some form of GBS.	First commercial application of GBS moves to construction.	Second project contracts using GBS. Considered as a commercially viable option.	Gravity base support structures considered competitive with other foundations at certain site types. At

					least two projects have contracted GBS with 10 - 20% of projects considering some form of GBS foundations.
Behind target	Test and demonstration of GBS concepts only.	Further/continuing trials of GBS concepts with first successful trial deployment.	Further/continuing trials of GBS concepts with a demo site operational	First commercial application of GBS moves to construction.	Second project contracts using GBS but results of demo uncertain.
Missed target	No progress in establishing any new test or demonstration of GBS concepts.	Test and demonstration of GBS concepts only.	Test and demonstration of GBS concepts only.	First project contracts using GBS	One project progressing to build

21.3 Evidence

21.3.1 Questionnaires

Category	Questionnaire response
Have you been involved with any trials of floating or lifted concrete gravity base structures? If so, please provide details.	
[WTG OEM]	No

[WTG OEM]	Yes. [COMPANY] [PROJECT] project 2009. We will install a floating array with [COMPANY] off [LOCATION] during 2017.
Designer / Survey	No
[WTG OEM]	Confidentiality considerations
[Developer]	No. Involvement from an investor perspective in [PROJECT].
[Foundation]	Yes. [PROJECT]
[Developer]	No
What are the potential barriers or potential benefits to you using gravity base structures?	
[WTG OEM]	The biggest barrier is the lack of suitable port infrastructure - this will only be built if there is a large enough pipeline (>100 WTGs say). This doesn't look likely for the foreseeable future
[WTG OEM]	Short term, gravity base structures are not suited to the seabed conditions of our demonstration site. In the future, each new site will consider a number of foundation solutions (including gravity bases), with the seabed conditions being the primary consideration.

[WTG OEM]	Concrete gravity bases remain higher cost than monopile and have very specific requirements for manufacturing locations which will limit deployment. Monopiles for shallow water and jackets for deeper water is our expectation.
[Foundation]	The barrier is the mass, which becomes radically unpracticable at current water depths and turbines size
Designer / Survey	Preparation of the seabed in some cases
[WTG OEM]	Industry mainstream: monopile or jacket
[Developer]	Barriers – cost, logistics of port facilities for larger bases. Benefits – cost at certain ground conditions and local employment at certain locations. Also insensitive to larger WTG models and longer design life relative to steel substructures.
[Foundation]	Barriers - market appetite for 'novel' technology combined with identifying suitable opportunities within the market that suit the use of GBSs (water depth and wave climate). Benefits - GBSs offer crane free installation, high local content as the concrete caissons would be fabricated as close as possible to the installation site, and low environmental impact. Previous experience also suggests that GBS solutions can be competitive by comparison with other solutions for the operating water depths.
Do you expect to use gravity base structures on your next or any future (before 2020) projects? If so please provide details.	
Designer / Survey	Aware of one French project which will use gravity base and the [PROJECT] demo in the UK.

[Developer]	Not ruled out as a feasible technology should site conditions dictate however.
[Foundation]	Yes, subject to market conditions
[Developer]	Unlikely due to lack of full scale demonstration.

21.3.2 Interview

Category	Interview response
Have you been involved with any trials of floating or lifted concrete gravity base structures? If so, please provide details.	
[Developer]	View on the use of Gravity bases is that it opens up sites that may not be viable, rather than representing a cost reduction for all sites. There is also work ongoing to reduce the typical cost of concrete structures, but cost reduction in itself may not be the primary motivation in selecting or working with GBS. Building a GBS is not a challenge, but having a location with sufficient space to manufacture at scale is a real constraint. Construction of for example 80 foundations could take multiple years, and would be a challenge and also may require the repurposing of harbours and upgrade facilities etc. This means investment in facilities has to go hand in hand with GBS deployment. [Developer] are currently learning an awful lot and using the demo project to gain knowledge and experience.

	The role of Gravity in future is likely to be a clever and viable niche, it probably would not be expected to displace monopiles or jackets in the long term. It is a standard civils project, but difficulty and challenge is the compact nature of sites or ports where construction can take place. GBS brings a tangible benefit in terms of local content, so gravity can offer the benefit of putting a significant package of work into communities very local to the offshore site.
Do you expect to use gravity base structures on your next or any future (before 2020) projects? If so please provide details.	
[WTG OEM]	Demo site has gravity jacket, hybrid design. Not too much in the way of specific information but does also feature a concrete transition piece.
[Foundation]	Do not believe gravity based foundations will threatened the use of monopiles in deeper waters. Large monopiles are established and will be around for a while
What are the potential barriers or potential benefits to you using gravity base structures?	
[WTG OEM]	Still not convinced that costs can be brought down to compete with monopiles. Also not sure how it would be economically possible to manufacture at scale, say for 100 units – where could they be built, do sufficient port facilities exist?

[Designer]	GBS could overcome issues around piling noise and availability of steel and could promote local UK content, who have improved opportunities for fabricating concrete as opposed to steel support structures. GBS could offer improved design life – a bridge for example has a design life of 110 years. The balance between CAPEX and OPEX is not currently optimised with a larger focus on CAPEX at present. GBS could help address this balance by improving the opportunities and capabilities for replanting towards the end of a turbines design life i.e. putting a larger turbine on an existing GB foundation.

21.3.3 Market intelligence

Evidence	Source
• In June 2016 BAM won the job to build and install the world's first five full-size gravity base foundations for wind turbines in the demonstration project off the Northumberland Coast. The turbines will generate 40 MW – enough low carbon electricity to power 33000 homes and the project has permission to install total generating capacity of almost 100 MW. Five 13,000 t gravity base structures will anchor wind turbines to the sea bed off the coast of Blyth to test the technology for wider use in the North Sea. Shepherd Engineering is preparing to start building the 30 m diameter concrete bases at the Neptune dry dock on the Tyne. Offshore work preparing the seabed and installing the 'float and sink' wind turbine bases will start in 2017. The contract awarded by EDF Energy Renewables brings to a culmination more than five years of intensive design work to prove the viability of installing gravity base foundations in the offshore environment for future wind farms. The foundation design will utilise 'self-installing' technology, which has been developed by two BAM companies, BAM Nuttall and BAM Infra. The design is being undertaken by BAM Infraconsult.	http://www.constructionenquirer.com/2016/06/07/bam-nuttall-to-build-worlds-first-wind-farm-gravity-bases/

• In the same month it was announced that St. John's, Newfoundland and Labrador company Beothuk Energy Inc. has awarded contracts through its engineering firm, Maderra Engineering, to Norwegian energy consultancy DNV GL and Canadian seafloor mapping specialists Fugro GeoSurveys, for its St. George's Bay offshore wind energy project in western Newfoundland, Canada. The St. George's Bay wind farm project is forecast to have a 180 MW capacity. Located about 30 km offshore in Bay St. George, the proposed C$466 million wind farm site will cover an area of 20 square nautical miles, with water depths averaging about 40 m, and will see 30 turbines on towers mated to gravity based structures, each generating 6 MW at a cost anticipated to be less than 10 cents per kilowatt-hour.	http://www.cantechletter.com/2016/06/beothuk-energy-awards-contracts-build-newfoundland-offshore-wind-farm/

21.4 Additional comments

None for this indicator

21.5 Recommendations

None for this indicator

22 Standardisation of Offshore AC Substation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Transmission asset CAPEX	HV AC (near / mid shore)	Standardisation of Offshore AC Substation

22.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016. There is evidence of divergent approaches towards the technology development described by this indicator. Certain portfolios in the UK and EU market are achieving noteworthy cost reduction through designing, fabricating and deploying standard substation designs. However, evidence also suggested that a number of developers do not necessarily see a ‘standardised design’ as something which can offer cost reduction potential to their projects.

In CRMF 2015 this indicator was also assessed as on target, again noting that where relevant there has been reasonable progress on the development and application of substations with standardised designs or standardised elements of design.

Outlook:

In the near future a number of standardised substations will be deployed on UK and EU projects by Dong and TenneT. Others may also converge on standard design as sizes of project portfolios increase. However there are also continuing evolutions in offshore transmission concepts which mean that it may not yet be a beneficial stage for some players to standardise, as locking in future designs now could restrict differing future approaches which also have the potential to reduce costs. As such all projects are unlikely to achieve the 2020 vision for this indicator of standardised design.

A ‘medium confidence’ was expressed by industry in the outlook for this indicator. This may represent the differing approaches, where some are seeking to standardise, and others are not. Standardisation at subsystem level was described as more likely in responses.

22.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Half of projects use standard rating and voltage. Industry 'reference design' is available to market. First project delivered using standardised design enter construction phase.	Almost all projects use standard rating and voltage. Some other features in process. First project using standardised design is delivered and shows significant benefits.	Almost all projects use standard rating and voltage. Some other features in process. Benefits of standardised design on real projects highlighted in industry.	All substations have standard rating and voltage, substantial standardisation of other features.	All substations have standard rating and voltage, substantial standardisation of other features.
On target	Further projects reaching FID achieve some form of standardisation	Half of projects use standard rating and voltage. Industry 'reference design' is	Almost all projects use standard rating and voltage. Some other features in	Almost all projects use standard rating and voltage. Some other features in	All substations have standard rating and voltage, substantial

	on voltage, rating or size. Work ongoing on 'reference design' for offshore substation.	available to market. First project delivered using standardised design enter construction phase.	process. First project using standardised design is delivered and shows significant benefits.	process. Benefits of standardised design on real projects highlighted in industry.	standardisation of other features.
Behind target	First projects reach FID using some form of standardisation on voltage, rating or size.	Further projects reaching FID achieve some form of standardisation on voltage, rating or size. Work ongoing on 'reference design' for offshore substation.	Half of projects use standard rating and voltage. Industry 'reference design' is available to market. First project delivered using standardised design enter construction phase.	Almost all projects use standard rating and voltage. Some other features in process. First project using standardised design is delivered and shows significant benefits.	Almost all projects use standard rating and voltage. Some other features in process. Benefits of standardised design on real projects highlighted in industry.
Missed target	0%.	Designers aim for standardisation of major characteristics of substation platforms: transformer rating, voltage, size.	First projects reach FID using some form of standardisation on voltage, rating or size.	Further projects reaching FID achieve some form of standardisation on voltage, rating or size. Work ongoing on 'reference design' for offshore substation.	Half of projects use standard rating and voltage. Industry 'reference design' is available to market. First project delivered using standardised design enter construction phase.

22.3 Evidence

22.3.1 Questionnaires

Category	Questionnaire response
Describe any steps you are taking to standardise offshore substations.	
Designer / Survey	N/A
[Developer]	We are not currently seeking to develop a standardised offshore substation with fixed capacity and fixed operating voltages. We feel that with difference in site capacities, distances from shore and different country regulations (e.g. export voltages) there are advantages in retaining flexibility. We do not dictate the detailed design to our suppliers. Large parts of our OSP functional technical specifications are standard.
Are you implementing a standardised substation design on suitable sites?	
Designer / Survey	N/A
[Developer]	It would be more accurate to say that we work on a process of continuous improvement, whereby our requirements for future OSPs are evolving based on lessons learned from earlier projects
What saving do you expect may be available from implementing a standardised design?	

Designer / Survey	N/A
[Developer]	We don't believe a standardised design necessarily results in an automatic cost saving & there is also a question of what does 'standard mean'. Without dictating the detailed design to our suppliers a functional specification will result in different detailed designs from different suppliers, i.e. even when supplying against the same technical specification.

22.3.2 Interview

Category	Interview response
[Electrical]	The industry in general, and [Electrical] as a key player have so far made many offshore substations and almost all are different. There has been a spiralling level of complexity and cost on offshore substation structures as more facilities/equipment/systems have been added.
[Designer]	[Designer] have completed 8 substation designs for [Developer]. This 'learn by experience' has helped to improve and standardise elements of their design and are building this learning into current and future designs. [Designer] believe that by keeping designs similar helps to bring down weight and associated costs. A positive step for the industry is introduction of OTMs which [Designer] are currently designing for Beatrice. The capacity to put certain components in the onshore substation and only the necessary components on the OTM significantly reduces costs. Placing

	the OTM on a wind turbine foundation can realise the full cost benefits of the design, where OTMs can be placed on the same foundation as a WTG saves on the fabrication, installation and O&M costs of a separate structure. Standardised substation designs still have their place over OTMs in some instances as not all countries will be able to place offshore substation components on onshore substations.
[Developer]	Both sites developed by [Developer] so far have no offshore substations, not much recent experience to add in grid infrastructure side.
[Developer]	Modular design for OSS
[Electrical]	In the first instance, each wind farm is different, so a completely standard substation is not possible. Switchgear is off the shelf, standard. SCADA system and control is more or less refined to a fairly standard offering, needs to be tweaked for each substation slightly, but almost standard. Clients are more or less coming with the same single line diagrams now, or at least typically much more similar than they would have been project to project in the past. Transformer is always bespoke to match the wind farm rating, which always varies depending on the site.

	In recent years there has been a trend in moving away from the over specified oil and gas style offshore platforms (enclosed topsides), but this is actually nothing new, think of early Round 1 sites e.g. the barrow substation design for example, this early offshore substation was one of the first, and is a containerised substation. Paint specifications – some clients add cost by over specifying to insist on offshore paint and material even for something that may be indoors on the substation in a controlled environment. Aim to have an indoor onshore environment offshore, as the best way to specify lowest cost components. Oil and gas influence ([COMPANY], [COMPANY] and other etc.) influenced the design of substations, making the last few years have had an extremely well appointed substations which have made very comfortable operational environments for what is often actually fairly basic offshore periodic maintenance. There is still ongoing learning and experience on both sides to find a balance in specifications, in terms of what is really required to go offshore, and as such no standard design. Voltage standardisation; higher voltage means more power, move from originally 120 kV – 150 kV cables now 220 kV has been driven by cables. If subsea/export cables could be manufactured to cope with 270 – 400 kV for example, then substations export more power and be more efficient, so limits in offshore transmission is at present typically imposed by the cable.

	If a cable supplier could provide a 400 kV XLPE subsea cable then this would be a game changer in terms of substation design. There can still be a struggle with specifications for substations, clients can still over specify by basing specs on oil and gas, they should be more realistic and more thorough in determining their specifications. [Electrical] have to always keep chipping away at these to help clients to reduce costs.

22.3.3 Market intelligence

Evidence	Source
• In March 2016, STX France-Offshore Energy has signed a contract with Rentel N.V. for the engineering, supply and installation of the Offshore Substation topside (approx. 1200 t) which will be installed 32 km off the Belgian coast in the Rentel offshore wind farm (309 MW). Delivery is scheduled for 2018.	http://www.4coffshore.com/windfarms/stx-to-supply-rentel-substation-nid3425.html
• In March 2016, Petrofac has awarded Heerema Fabrication Group (HFG) a contract for the fabrication of the substation platform for Galloper offshore windfarm. Heerema Hartlepool is fabricating the unmanned offshore substation platform however project engineering and procurement are being undertaken by Petrofac as part of	http://www.4coffshore.com/windfarms/heerema-awarded-galloper-gig-nid3417.html+X83:A

the GE Petrofac Consortium. The Galloper substation platform will connect turbine generators to a single Offshore Substation Platform (OSP) by subsea array cables.	D83X83:AC83X83:AB83X83:AA83X83:Z83X83:Y83
• TenneT, charged with contributing towards offshore wind's 40% cost reduction goals set by Dutch government, will produce five identical and standardised offshore substations to connect 3.5 GW of capacity across three development zones, interlinking two wind farms each, allowing for efficiencies in design, supply, installation and maintenance. In December 2015, TenneT signed framework agreements for the supply of GIS (Alstom Grid Netherlands) and transformers (CG Power Systems). Identical equipment will be installed on all platforms, optimising design and maintenance. Each platform is equipped with two 230/66 kV 400 MVA power transformers, one 66 kV GIS and one 230 kV GIS. In September 2015, TenneT launched a qualification system for several tenders for one or more platforms.	http://www.4coffshore.com/windfarms/tennet-issues-tender-for-borssele-offshore-substation-nid3552.html+X83:AD83X83:AC83X83:AB83X83:AA83
• In April 2016, TenneT has issued a tender for the Certification of the Borssele Alpha Platform by a certifying authority during the construction phase of the project. There is also an option for the tender to carry out certification of the Borssele Beta Platform. The Borssele Alpha Platform will be used to interlink the Borssele site 1 and Borssele site 2 wind farms. The Borssele Beta Platform will link Borssele site 3 and Borssele site 4. The platforms will be standardised in order to reduce costs and will be located 25 km west off the Dutch coast. The offshore substations are to carry high-voltage switching and transformation equipment as well as auxiliary facilities. Intake power from the wind farms will be 66 kV, export power will be 220 kV. The 4500 t topsides will measure 45 m in length with a width of 21 m and a height of 30 m. The weight of the jacket is approximately 2000 t. TenneT stated that the substations will be unmanned and all control will be carried out from the onshore control centre.	https://www.linkedin.com/pulse/horizon-offshore-substation-technology-richard-aukland
• In September 2016, DNV GL has awarded Innogy SE the project certificate for its Nordsee Ost offshore wind farm at this year's WindEnergy Hamburg exhibition. The certification was carried out according to the German	http://www.yourrenewablenews.com/dnv+gl

Federal Maritime and Hydrographic Agency (BSH – Bundesamt für Seeschifffahrt und Hydrographie) standard defined by the BSH 7005 edition 2007, and covers all stages of the project development from design planning to commissioning including the wind farm's turbines and offshore substation. It is one of the first offshore wind farms to be awarded with a full project certificate in Germany and comprises 48 turbines with an installed capacity of 295 MW.	+certifies+nordsee+ost+offshore+wind+project+for+innogy_137127.html
• On 05/10/16 the Spanish company Navantia won a £56m contract to fabricate the offshore substation for Scottish Power Renewables' 714 MW East Anglia 1 wind farm off the UK coast. The topside and jacket will weigh 7700 tonnes and will be manufactured at the company's Puerto Real yard in Cadiz.	http://renews.biz/104455/navantia-wins-ea1-substation-job/

22.4 Additional comments

None for this indicator

22.5 Recommendations

None for this indicator

23 Lightweight or novel offshore substations

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Transmission asset CAPEX	HV AC (near / mid shore)	Lightweight or novel offshore substations

23.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
N/A	On target	N/A	High confidence

Finding: On target

Marked as ‘on target’ for 2016 as there has been good progress by several projects which are seeking to deploy a form of radically different transmission architecture, including projects which have taken FID and will progress to construction imminently. Specifically the Beatrice project in the UK is anticipated to see the first deployment of the Siemens OTM concept and will use two lightweight substation topsides on a foundation design shared with the WTG support structures.

This is a new indicator for CRMF 2016 and as such was not scored individually in CRMF 2015, however some content relating to distributed transmission assets was included in the ‘standardisation of offshore AC substation’ indicator milestones and has been removed to form the core of this now separate indicator. The standardisation indicator was assessed as being ‘on target’ last year.

This indicator could not be considered to be ‘ahead of target’ for this year as there remains potential for further cost reduction both through a continued technology evolution at a concept and detailed level, but also through the entry of alternative suppliers

The emergence of disruptive technology concepts such as the Siemens OTM system offers the potential for significant CAPEX savings from an offshore transmission asset. There are regulatory and technical barriers which must be overcome in order to make this leap successful for a developer, but there is evidence these being overcome. An additional attractive feature of the OTM solution particularly is the level of UK content (now a government priority). The Siemens OTM solution will be designed, developed, fabricated and deployed on a project first in the UK, and is an example of how industries supporting offshore wind are well established in the UK and can bring both local content and CAPEX benefits to projects simultaneously.

Outlook:

The concept of lightweight or novel offshore transmission architectures is expected to increase in popularity, but for project specific reasons may not displace a more standard offshore substation platform(s) on projects in the near term. A technical challenge for the future remains in the desire to co-locate transmission and generating assets on a shared foundation, which has been described conceptually but based on engagement still presents a significant hurdle. It also remains to be seen whether sufficiently close integration of turbine OEM and transmission asset OEM could be achieved elsewhere in the supply chain to enable a range of products to come to the market, as at present this is a solution available only to customers of a single OEM.

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, reflecting a mood of positivity about likely technical progress and cost reduction contributions in this area in the next few years.

23.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	First project contracts with	First project contracts with	third project contracts with	Three projects contract with	More than three installation started

	lightweight transmission system and > 2 market ready products	lightweight transmission system and > 2 market ready products	lightweight transmission system and > 2 market ready products	lightweight transmission system, at least 1 in operation and > 2 market ready products	on distributed transmission system infrastructure on commercial scale wind farm
On target	First project contracts with lightweight transmission system	First project contracts with lightweight transmission system and > 2 market ready products	Second project contracts with lightweight transmission system and > 2 market ready products	Second project contracts with lightweight transmission system and > 2 market ready products	Three projects contract with lightweight transmission system, at least 1 in operation and > 2 market ready products
Behind target	Initial discussions to include lightweight transmission systems ongoing	Initial discussions to include lightweight transmission systems ongoing	First project contracts with lightweight transmission system	First project contracts with lightweight transmission system	Second project contracts with lightweight transmission system and > 2 market ready products
Missed target	No development of lightweight transmission system infrastructure	No development of lightweight transmission system infrastructure	No development of lightweight transmission system infrastructure	No development of lightweight transmission system infrastructure	First project contacts with lightweight transmission system

23.3 Evidence

23.3.1 Questionnaires

Category	Questionnaire response
Discuss any projects you are aware of which are seeking to deploy unconventional offshore transmission arrangements, (e.g. lightweight substations, distributed substations or substations on turbine foundations)	
[WTG OEM]	[PROJECT] + [PROJECT]considering the [COMPANY] Offshore Transformer Module concept
[WTG OEM]	[COMPANY] offering OTM solution which will be deployed on [PROJECT] and other projects.
[WTG OEM]	Not applicable
[Developer]	We are currently actively following this technology and seeking to employ it to some level on our projects. We expect to see a number of projects adopting this technology as a means of exploiting new latitude in the SQSS and reduce sub-structure costs.
[Developer]	None within portfolio, see consent applications for future project considered options.

If you are considering novel offshore transmission asset arrangements please comment on the level of cost saving anticipated, if any.	
[WTG OEM]	Approx. 5% LCOE depending on the project
[WTG OEM]	Up to 40% saving against traditional substation platform anticipated
[WTG OEM]	Not applicable
[Developer]	We anticipate cost reductions in the region of 10-20% may be possible when considering the cost of the offshore wind transmission assets.
[Developer]	What is defined as novel? Offshore project are high capital projects, technologies must be derisked, I would not describe new technologies and techniques as novel.
What are the potential barriers to adopting novel offshore transmission asset concepts?	
[WTG OEM]	Having a close link with the supply chain

[WTG OEM]	None, Some complexity on OFTO regulations means we are unlikely to deploy transformer and turbine on a single foundation, so OTM likely to be stand alone on a modified turbine foundation.
[WTG OEM]	Not applicable
[Developer]	Safety in design is key consideration for adoption of this technology to ensure that the standards adopted by the industry are maintained. In addition the designs are currently unproven in terms of installation. Cable installation, commissioning and operations all require close attention.
[Developer]	Solutions must be proven and support the business case, e.g. bankable
Do you expect the norm in offshore transmission asset concept to change in the coming 3 - 5 years, if so, how?	
[WTG OEM]	Unsure if the OTM concept will be adopted on a widespread basis given that it's a [COMPANY] proprietary design
[WTG OEM]	More deployment of OTM. Far shore projects will still require traditional solutions or HVDC
[WTG OEM]	Not applicable

[Developer]	A mixture of conventional (topside/jacket) and novel (lightweight OTM type) transmission concepts are anticipated. Some far shore projects will likely be HVDC.
[Developer]	Uncertain what term the current norm refers to

23.3.2 Interview

Category	Interview response
Discuss any projects you are aware of which are seeking to deploy unconventional offshore transmission arrangements, (e.g. lightweight substations, distributed substations or substations on turbine foundations)	
[WTG OEM]	What is actually needed is the cheapest and most simple offshore transformer.
If you are considering novel offshore transmission asset arrangements please comment on the level of cost saving anticipated, if any	
[WTG OEM]	Building onto jackets where you only have to make another one of the same foundation still offers a substantial cost saving when comparing to traditional substation platform which can require extremely expensive offshore heavy lifts. Vessel cost for a 2000 t offshore lift is extremely high and constrained in availability.

What are the potential barriers to adopting novel offshore transmission asset concepts?	
[WTG OEM]	If a transformer and turbine were mounted on the same turbine then emergency procedures and organisational complexity arises around operations where an OFTO and operator are both working on the same platform with certain accesses restricted etc.
[Designer]	They are currently designing the substations for Beatrice. [Designer] believe that by keeping designs similar helps to bring down weight and associated costs. A positive step for the industry is introduction of OTMs. The capacity to put certain components on the onshore substation and only the necessary components on the OTM significantly reduces costs. Placing the OTM on a wind turbine foundation can realise the full cost benefits of the design, where OTMs can be placed on a monopile or jacket – they are not restricted to jackets. Standardised substation designs still have their place over OTMs in some instances as not all countries will be able to place offshore substation components on onshore substations.

23.3.3 Market intelligence

Evidence	Source
• In January 2016, a report published by Offshore Wind Programme Board (OWPB) titled "Lightweight Offshore Substation Designs". This report describes the concept of a “lightweight” offshore substation and the implementation of this concept developed by Siemens: the Offshore Transformer Module (OTM). The two other concepts developed by ABB and DONG are briefly described as well. The three concepts are:	https://ore.catapult.org.uk/wp-content/uploads/2016/05/Lightweight-

a) ABB's Distributed AC Power Collection that comprises a single 175 MVA 220/66 kV14 transformer, three bays of 66 kV switchgear and three bays of 220 kV gear. This substation was to share a modified wind turbine substructure with a 6 MW-class wind turbine. b) DONG's Distributed Substation comprising a single 200 MVA 220/33 kV15 transformer, a 90 MVar 220 kV shunt reactor, and 220 kV and 33 kV switchgear. Topsides weight is slightly less than 1000 t and substructures are to be based on the design used by the wind farm's turbines. The substructure is not shared with a wind turbine and the substation retains many of the features of conventional offshore substations such as relatively large cranes and a backup diesel to provide an emergency supply to the platform. c) Siemens's Offshore Transformer Module (OTM) concept which appears to be much more advanced than that of either DONG or ABB, with detailed design work expected to start within a few months and final investment decisions on more than one OTM-using project expected within 12 months.	Offshore-Substation-Designs.pdf
• In June 2016, an article titled: "On the Horizon: Offshore Substation Technology" by Richard Aukland, Director of Research at 4C Offshore, stated that Siemens' OTM, which was originally developed for a particular offshore wind farm comes in two base designs which can be modified to site specific requirements: a 'standalone' version where the topside has its own substructure and an 'integrated' design where the topside shares a substructure with a wind turbine.	https://www.linkedin.com/pulse/horizon-offshore-substation-technology-richard-aukland
According to Andreas Barth, Siemens' Head of Grid Access Solutions, their OTM is the new gold standard. Four key features set this third-generation model apart from conventional, more bespoke substations currently in the market: - Simple design, with no moving parts;	https://www.siemens.com/customer-magazine/en/home/energy/power-transmission-and-distribution/an-

- more environmentally friendly, by making the use of mineral oil obsolete; - one-third less weight and volume than a conventional AC platform; and thus, - a cost reduction of up to 40%. Scottish energy giant SSE has contracted to install the first of these AC transformers in its 588 MW Beatrice wind power plant. To provide the required transmission capacity, the OTM's will be linked together. The new wind power development will go live in 2019, off the northernmost coast of Scotland.	offshore-substation-slims-down.html
• In November 2015, the Security and Quality of Supply Standard (SQSS) Review Panel has evaluated the proposal (GSR020) for the modification of Clause 7.8.1.1. to allow single transformer offshore substations of capacity greater than 90 MW. The group accepted the new interpretation of the SQSS allowing single transformer offshore platforms above 90 MW to be considered SQSS-compliant without a design variation in comparison with the traditional single platform with multiple transformers.	http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=43650

23.4 Additional comments

None for this indicator

23.5 Recommendations

None for this indicator

24 Overplanting and/or use of dynamic rating

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Transmission asset CAPEX	HV AC (near / mid shore)	Overplanting and/or use of dynamic rating

24.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ for 2016. There is evidence that developers are at least considering both of these potential ways to export additional capacity from the windfarm. However, it has also been an area where engagement has been challenging, and where there has generally been a reluctance to share much information.

Last year the indicator was ‘on target’ noting that there was use of dynamic rating, but that overplanting had not been evidenced. It was noted that the potential benefit available was thought by some participants was significant.

Since it is uncommon for a project to reach site wide maximum generating capacity there is a significant potential to reduce by paring back export system specifications. Developers can decide to either oversize generating capacity in relation to fixed specification of electrical infrastructure or allow cables to temporarily transfer more load than they are rated for. Dynamic rating requires condition monitoring of

cables and both practices will have important implications for the OFTO. There have been public announcement from European projects describing how these techniques will be used, but it is not clear how many UK projects may take a similar approach in the future, and the differences in transmission asset ownership may provide a barrier.

Outlook:

Looking forward it does seem likely that as projects become ever more competitive and the trend for continued cost reduction continues, that increasingly developers will focus on how to get the most out of the transmission assets, and it is expected the adoption of overplanting and dynamic rating will therefore increase, evidence from recent low cost projects announced in the EU suggest that overplanting and dynamic rating can be an attractive ingredient for a low cost offshore wind project, and demonstrates that when sufficient technical knowledge and collaboration is employed it is possible to design an offshore wind project to include significant overplanting.

A ‘high confidence’ was expressed by the industry in the outlook for this indicator. However, the average score is just above the threshold of ‘medium confidence’, and as such suggests that some uncertainty remains about how to practically and commercially unlock all of the cost reduction potential which could be contributed by passing a larger amount of energy through export cables for future projects.

24.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Use of overplanting and/or dynamic rating on 50% of projects.	Use of overplanting and/or dynamic rating on 75% of projects.	Use of overplanting and/or dynamic rating on 75% of projects.	Use of overplanting and/or dynamic rating on all projects.	Use of overplanting and/or dynamic rating on all projects.
On target	First project under construction.	First project operational using overplanting and/or dynamic cables rating. IEC publishes	Over 25% of projects use the approach.	Over 50% of projects contract using the approach.	Over 50% of projects reaching FID overplant or use dynamic cables.

		'wind generation' cable rating standard. At least another project contracts using the approach.			
Behind target	First project contracts using overplanting and/or dynamic rating. IEC cable rating for wind generation being developed.	First project under construction.	First project operational using overplanting and/or dynamic cables rating. IEC publishes 'wind generation' cable rating standard. At least another project contracts using the approach.	Over 25% of projects use the approach.	Over 25% of projects contract using the approach.
Missed target	Some use of overplanting and/or dynamic rating on at least one project.	Some use of overplanting and/or dynamic rating on at least one project.	Some use of overplanting and/or dynamic rating on at least two projects.	Some use of overplanting and/or dynamic rating on at least two projects.	Some use of overplanting and/or dynamic rating on 50% of projects.

24.3 Evidence

24.3.1 Questionnaires

Category	Questionnaire response

Discuss whether you seek to optimise export cable and electrical infrastructure to generating capacity, or to what extent generating capacity is driven by electrical considerations.	
[Developer]	Sizing of installed capacity and optimising transmission assets is a key part of the FEED process. This requires supply chain engagement in terms of supporting design studies and ensuring that the correct balance is struck between installed capacity, losses and site conditions. We expect that the technical limits of electrical transmission infrastructure will be exploited to a greater extent than has happened in the past, as projects strive for continued cost reduction.
[Developer]	The project grid connection is a ‘generator build’ the project requires to comply with the Grid Connection Agreement, national Grid CION’s process, Grid Code, STC and Ofgems requirement for economically and efficient design. Within these constraints the design is optimised.
Are you aware of any projects considering over-sizing the wind farm generation capacity to the export infrastructure? (e.g. 518MW wind farm with 500MW export infrastructure). If so, please detail.	
[Developer]	Yes, overplanting is a key consideration in site design.
Are you considering or using dynamic rating of export cables and electrical infrastructure on any of your projects? Please provide details.	
[Developer]	Private
[Developer]	It is being considered. Cables must comply with design standards and usage, ‘dynamic rating’ can cover a wide range of scenarios.

Do you expect this to change in the future?	
[Developer]	No

24.3.2 Interview

Category	Interview response
None for this indicator	

24.3.3 Market intelligence

Evidence	Source
• In November 2015, DONG Energy announced an offer for a project Thesis titled "Analysis of overplanting for large offshore wind farms" aiming to provide an assessment of the benefits and disadvantages of so-called overplanting in large offshore wind farms. The evaluation was to be done in terms of capital expenditure (CAPEX) and net present value (NPV). The base for comparison should be state-of-art design.	https://www.jobindex.dk/vis-job/h569318
• In April 2016, the Carbon Trust has awarded a £375,000 contract for dynamic thermal rating of subsea cables (DTR) to the Kenilworth-based Transmission Excellence Ltd as part of the Offshore Wind Accelerator (OWA)	http://www.offshorewind.biz/2016/04/15/the-carbon-trust-looking-into-subsea-

initiative. The focus of this project is to look into the thermal optimisation of subsea cables in the operating conditions of offshore wind farms.	cable-thermal-optimisation/
• A report issued to ORE Catapult on May 2016 titled "HV cables dynamic ratings review for offshore wind farms" investigated the transient thermal response of a series of offshore wind farm export cables in two installation environments through a series of bespoke finite element models. This report concluded that whilst it is possible to operate a wind farm above the continuous rating of the export connection, there is a critical percentage of the continuous rating where the levels of curtailment begins to unfavourably increase.	https://www.thecrownestate.co.uk/media/761939/owpb-hv-cables-dynamic-ratings-review-for-offshore-wind-farms.pdf
• In June 2016, DONG Energy won the tender for Dutch 700 MW offshore wind farms: Borssele I and II. Wind Farm Zone Borssele, 344 km^2 in total, is divided into 5 sites. Sites I, II and IV can accommodate 350 MW plus 30 MW overplanting. Site III can accommodate 320 MW plus 30 MW overplanting. Site V is for innovations and can accommodate 20 MW.	http://www.windpowerengineering.com/construction/dong-energy-wins-tender-dutch-700-mw-offshore-wind-farms/
• In March, Statoil announced it will install a pilot 1 MWh lithium-ion battery system to store energy from the 30 MW Hywind pilot park off the coast of Peterhead in Aberdeenshire, Scotland, the world's first floating wind farm. The Batwind system will look to capture wind overshoots, reduce balancing costs and increase power market value. Other possible uses include network applications like ancillary services. One major application Statoil will be testing will be the use of storage to capture spilt energy from "overplanted" offshore wind farms, where the wind farm's rated capacity is above the grid connection capacity. The ability to store excess electricity or sale when capacity is free could potentially reduce the levelized cost of offshore wind and boost revenue via an increase in MWh exported. Bringsværd said Statoil expects the initial revenue gains from the pilot overplanting to be small, though its potential benefits could still be significant with commercial-scale deployment. Everoze's modelling	http://analysis.energystorageupdate.com/statoil-trial-triple-revenue-stream-offshore-wind-storage-project

shows that for a 1.2 GW offshore wind farm with a 1 GW grid connection, overplanting could amount to a revenue uplift of up to 4%. From a grid perspective, this can help make offshore wind projects look a little closer to baseload power. However, the capex investment required to deliver this overplanting application is currently prohibitively high, though this could change in the future as technology and system costs decrease and companies find an optimal revenue stack, according to Baldock. For offshore wind, the bar will always be higher, as capital and operational costs increase when moving offshore, Baldock added.	

24.4 Additional comments

None for this indicator

24.5 Recommendations

None for this indicator

25 Increased capacity export cables

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Transmission asset CAPEX	HV AC (near / mid shore)	Increased capacity export cables

25.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
N/A	On target	N/A	Medium confidence

Finding: On target

Marked as ‘on target’ in 2016 because there is evidence to support an ongoing increase in the individual capacity of high voltage subsea export cables which are considered commercially available.

Outlook:

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator. It looks reasonably likely that technology advances will enable an ongoing gradual increase in the individual capacity of high voltage subsea export cables.

25.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Maximum individual cable capacity of export cables is around 460 MW. At least one project reaches FID using this capacity of export cables. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 490 MW. At least one project reaches FID using this capacity of export cables. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 520 MW. At least one project reaches FID using this capacity of export cables. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 550 MW. At least one project reaches FID using this capacity of export cables. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 580 MW. At least one project reaches FID using this capacity of export cables. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.
On target	Maximum individual cable capacity of export cables is around 430 MW. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 460 MW. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 490 MW. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is around 520 MW. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.	Maximum individual cable capacity of export cables is in around 550 MW. Demonstrable cost savings are described by projects able to utilise a smaller number of higher capacity cables.

Behind target	Maximum individual cable capacity of export cables is around 400 MW.	Maximum individual cable capacity of export cables is around 430 MW.	Maximum individual cable capacity of export cables is around 460 MW.	Maximum individual cable capacity of export cables is around 490 MW.	Maximum individual cable capacity of export cables is around 520 MW.
Missed target	Maximum individual cable capacity of export cables is less than 370 MW.	Maximum individual cable capacity of export cables is less than 400 MW.	Maximum individual cable capacity of export cables is less than 430 MW.	Maximum individual cable capacity of export cables is less than 460 MW.	Maximum individual cable capacity of export cables is less than 490 MW

25.3 Evidence

25.3.1 Questionnaires

Category	Questionnaire response
What is the largest export cable capacity you have used on a project to date?	
[Developer]	Constructed @200MW, Planned @340MW
Do you have plans to deploy higher capacity export cables on your next or any future (before 2020) projects? If so please provide details.	
[Developer]	Depends of transmission technology, distance from shore, installation conditions and available cable sizes.
Discuss the influence of the capacity of export cables on overall transmission system and wind farm concept design.	

[Developer]	Maximum rating of export determines size of wind park, also assess active and reactive compensation.
[Developer]	It is a key consideration when developing the overall project through life cost
Do you expect to see increased capacity export cables coming to market in the next few years?	
[Developer]	Up to a limit, capability of manufacturers limited.
[Developer]	Yes, but these are just part of the overall system and transmission capacity, there are many other limiting design factors. Not just bigger cables
What do you consider industry standard and largest proven export cable capacities (MW per individual cable)?	
[Developer]	There is none. Dependant on installation conditions, size of cable etc. e.g. same cable will have a rating of x Amps in …… and 7/8 x Amps in the Mediterranean Sea.
[Developer]	DC – 2.4 GW AC – depends on distance and voltage.

25.3.2 Interview

Category	Interview response

[Electrical]	Voltage standardisation; higher voltage means more power, move from originally 120 kV – 150 kV cables now 220 kV has been driven by cables. If cables could be manufactured to cope with 270 – 400 kV for example then substations could be improved, could export more power and be more efficient, so limits in offshore transmission is at present typically imposed by the cable.
[Electrical]	SQSS requirement means that you need two cables, so some designs have ended up with two very large cables, not a big cost increase for installation, so if you have to install cables then lay the biggest one you can get, and design electrical system around this, this may be unusual compared to what has gone before. Adding as many turbines as possible to push max that you can manage through the cables, increased voltage would allow even more. 275 kV would be a natural step as equipment is already available, this could allow more capacity per cable again. 275 kV cables would allow use of 275 kV equipment, which is standard elsewhere.

25.3.3 Market intelligence

Evidence	Source
• The third deep water installation campaign of the Western Link HVDC cable was planned to commence at the beginning of July, according to a Notice to Mariners issued on AWJ Marine's website. The work will be carried out in the North Channel of the Irish Sea between Scotland and Northern Ireland for about 120 km, and is expected to be completed in September 2016. The Western Link Project consists of installing two 600 kV DC submarine cables in the Irish Sea from Ardneil (Scotland) to Wirral (England) for a total route length of about 387 km. The cables will usually be laid as two separate cables approximately 30 metres apart. The third campaign of about 120 km is being installed from south to north. National Grid and Scottish Power Transmission have come together in a joint venture to build the Western Link, a £1 billion project which will help to bring renewable energy from Scotland to homes and	http://www.offshorewind.biz/2016/06/28/western-link-hvdc-cable-laying-to-start-soon/

businesses in Wales and England. Construction of the Western Link is being carried out by a consortium of Siemens and Prysmian.	
• In September 2016, Nexans announced that HVDC (High Voltage Direct Current) power links are now able to utilise Nexans' XLPE cables that are qualified to 320 kV, while type testing at 525 kV has just been successfully completed. At the same time Nexans has qualified the first 600 kV mass impregnated cable with a paper-based insulation.	http://www.4coffshore.com/windfarms/nexans-reach-hvdc-cable-milestone-nid4560.html
• Dutch Transmission System Operator (TSO) TenneT and its Danish counterpart Energinet.dk have signed contracts with Siemens and Prysmian for the construction of the COBRA cable between the Netherlands and Denmark. Siemens will supply two converter stations for the direct-current (DC) connection: one in Eemshaven (Netherlands) and one in Endrup (Denmark). Prysmian will supply the DC cables and offshore installation works. Scheduled for completion in 2019, the COBRA cable is a new, over 350 km long subsea DC connection (interconnector) that will create a direct link between the Dutch and Danish power grids. The cable will have a total capacity of 700 MW, which equivalents to the annual electricity consumption of 700,000 households.	http://www.marinetechnologynews.com/news/subsea-cable-netherlands-denmark-527490
• Scottish Power Renewables is considering alternative electrical solutions of HVDC and Low Frequency Alternating Current (LFAC) for the East Anglia Three Offshore wind farm's connection grid connection. One of the export solutions deemed appropriate for the East Anglia Three project is a Low Frequency High Voltage Alternating Current (LF HVAC, ot LFAC) connection. The National Grid system in the UK is designed to hold AC at a frequency of 50 Hz, and as a result most of the offshore wind farms located close to the coast are designed accordingly. However, when it comes to very long transmitting distances, distance greater than approximately 100km, the amount of electrical losses along the HVAC connection renders the solution very inefficient.	http://www.4coffshore.com/windfarms/scottishpower-renewables-investigates-low-frequency-

	transmission-for-ea3-nid4661.html

25.4 Additional comments

None for this indicator

25.5 Recommendations

None for this indicator

26 Booster stations (additional platforms midway to shore)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Transmission asset CAPEX	HV AC (near / mid shore)	Booster stations (additional platforms midway to shore, to reduce reactive power problem for AC transmission)

26.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because one project (Hornsea project one) has announced that it will use this technology solution, and that a fabrication contract has been awarded to Babcock in Rosyth, who have started construction.

Last year this indicator was assessed as ‘on target’ noting that two projects were known to be considering this concept at FEED stage, but that the concept was not yet thought technically proven.

Some conservatism remains around this technology, whilst it is certain to be used as part of the transmission asset on at least one project, it is unlikely to be suitable for all sites, and may not represent the optimum technical solution.

Outlook:

Similar to the finding in CRMF 2015, the future deployment of this technology on applicable sites hinges on the successful deployment on a project. It may also not be applicable to all projects, but it does look likely that it will at least be considered as a viable option at FEED stage by developers who are working on suitable sites.

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, reflecting the understanding that at least one UK project is expected to deploy this technology by 2020.

26.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	First project under construction	First project under construction	First project operational using booster stations	First project built using booster stations	Adopted in more than one project.
On target	First project contracts using booster stations	First project under construction	First project under construction	First project operational using booster stations	First project built using booster stations
Behind target	Considered in detail in FEED studies	Considered in detail in FEED studies	Considered in detail in FEED studies	Considered in detail in FEED studies	First project contracts using booster stations
Missed target	R&D task	R&D task	R&D task	R&D task	Considered in detail in FEED studies

26.3 Evidence

26.3.1 Questionnaires

Category	Questionnaire response
Describe your approach to AC transmission infrastructure (e.g. HVAC with booster)	
Designer / Survey	N/A
[Developer]	Before selecting an AC or DC transmission solution we would undertake through life cost benefit analysis to determine the most cost effective solution. In undertaking this analysis we would include assessment of any technical barriers (e.g.) transmission distance and how they may be overcome (e.g. reactive compensation solutions). Irrespective of whether AC or DC transmission is selected we would undertake optioneering to determine the most economic transmission solution for a given project.
[Developer]	Describe what is meant by booster, e.g. mid-point reactive compensation. The overall system design has to be cost effective, provide expected availability and be consentable. ‘Boosters’ are considered in the early feasibility.
Have you considered AC reactive power compensation technology in your FEED studies?	

Designer / Survey	No
[Developer]	Yes
[Developer]	Early review, FEED applies to detailed studies where the basic concepts are locked in.
If so, which project have you considered it for?	
[Developer]	All AC connected projects
[Developer]	Far offshore UK projects
Discuss whether you are able to offer AC booster stations (additional platforms midway to shore, to reduce the reactive power problem for AC transmission) and whether these offer a competitive alternative to HVDC.	
Designer / Survey	N/A
[Developer]	We have not had the need to use this solution to date.
[Developer]	See comment above

Have you taken any orders for AC booster stations over the last year?	
Designer / Survey	No
[Developer]	No
[Developer]	No

26.3.2 Interview

Category	Interview response
[Electrical]	Have bid to supply components to [PROJECT] reactive power compensation platform. As far as they know this is the only project in the UK/EU that is considering this solution at present. Large reactors and dynamic compensation required at the onshore end, and there are large electrical losses. [Developer] are clearly accepting the losses where they think they can win the job and still be economical with this kind of AC approach, and have found a commercial balance where this solution with the inherent electrical losses can still make a viable project.

26.3.3 Market intelligence

Evidence	Source
• Danish utility Dong Energy has awarded a "multi-million pound" contract to UK engineering support services company Babcock for the construction of what it says will be the world's first reactive compensation station (RCS) for its giant 1.2 GW Hornsea 1 wind array off the UK coast.	http://www.rechargenews.com/wind/1432836/babcock-to-build-pioneering-rcs-as-dong-awards-hornsea-1-deals

26.4 Additional comments

None for this indicator

26.5 Recommendations

None for this indicator

27 Compact HVDC systems

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Transmission asset CAPEX	HV DC	Compact HVDC systems

27.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Missed target	↓	▪ Low confidence

Finding: Missed target

Marked as ‘missed target’ in 2016 because it looks highly unlikely that any non-German project will contract HV DC grid architecture, and it is almost certain that this will not happen before 2020. Some of the projects currently in development and construction would originally have been planned to build HV DC transmission assets, but none have announced design work beyond concept phase to develop HV DC.

Last year this indicator was assessed as ‘behind target’ noting particularly that progress demonstrated in the AC transmission indicators of this study supports a suggestion that the distance over which an AC transmission link is considered viable is continuing to increase.

Evidence also suggests this year as in 2014 and 2015 that there continues to be a reluctance from developers to seriously consider HV DC transmission systems for two main reasons; Firstly similar projects executed on German offshore wind projects have had high profile challenges, have been extremely expensive and have required long design and build schedules. The second consideration in the UK is the

compressed timelines available to developers under CfD and the requirements to have confidence in commissioning dates and programme, developers do not see HV DC technology as compatible with the dynamics of UK projects.

Outlook:

As described above it looks unlikely that HV DC will see application on a UK project in the medium term. Looking further, some 'round 3' projects which exist at a concept/planning stage currently could still potentially benefit from specifying HV DC connections. Such projects may already be considering what the support structure may look like in 2025 and beyond. Speculating about how projects may be developed free of any significant subsidy could see 'hub and spoke' type shared offshore (HV DC) transmission assets once again look feasible, but this is well beyond the duration of scope of this study.

A 'low confidence' was expressed by industry in the outlook for this indicator in future. It was consistently felt that significant progress in HV DC systems is unlikely for any UK projects in the near or medium term.

27.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	At least one non German project contracts using HVDC export system	HVDC delivered on time and on budget with costs starting to fall. Competitive at 70 km	At least second non-German project contracts using HVDC	Reduction in costs to allow HVDC to be competitive at 60 km	Reduction in costs to allow HVDC to be competitive at 40 km
On target	More than 1 non German project contracts using HVDC export system	More than 1 non German project contracts using HVDC export system	HVDC delivered on time and on budget with costs starting to fall. Competitive at 70 km	At least second non-German project contracts using HVDC	Reduction in costs to allow HVDC to be competitive at 70 km

Behind target	First non-German project contracts HVDC	First non-German project contracts HVDC	More than 1 non German project contracts using HVDC export system. Costs falling	More than 1 non German project contracts using HVDC export system. Costs falling	HVDC delivered on time and on budget with costs starting to fall. Competitive at 70 km
Missed target	No non-German (hub and spoke) project uses HVDC	No non-German (hub and spoke) project uses HVDC	No non-German (hub and spoke) project uses HVDC	First non-German project contracts HVDC	First non-German project contracts HVDC

27.3 Evidence

27.3.1 Questionnaires

Category	Questionnaire response
If relevant, describe your planned approach to building HVDC transmission systems.	
[Developer]	We would only select HVDC transmission if it was shown to offer the most cost effective transmission solution (see also Answer 217) We have not enter detailed FEED studies for HVDC solutions at this time, nor have we determined the most appropriate procurement strategy.
[Developer]	Is this related to the consent process to get planning consent? Sketch out the realistic worst case envelope include in planning application and hope it is approved.

Describe any initiatives ongoing to reduce the cost of HVDC export systems.	
[Developer]	Initiatives have mainly been those R&D programmes progressed by the OWA (e.g. removal of need for AC substation, simplified HVDC technology …)
[Developer]	n/a

27.3.2 Interview

Category	Interview response
[Electrical]	Really difficult to say what may happen around DC, and what length of link would require it, expect that [PROJECT] at greater than 150 km may have to move to DC. The cost of putting the equipment offshore is very large. [Electrical] have some experience from their HV DC 800 MW German platform, HV DC plant is a huge cost, platform over 10,000 t and will take longer than AC to design and build, probably around 5 years. Can't see any UK projects going DC, as electricity price is too low, and feeling is that gas will be primary motivation of UK government for next 10 years, meaning that projects that would benefit from HV DC will not be built in the near future. Politics in Germany is different and so they are willing to pay the cost of doing this. No sharing of grid links in the UK, so CfD doesn't allow you to do that.

27.3.3 Market intelligence

Evidence	Source
• In 26/10/15, Siemens has introduced a new solution for connecting offshore wind turbines to the grid. Presented at the National Maritime Conference in Bremerhaven, this direct-current technology enables a cost-efficient and simplified connection of offshore wind power plants far from the coast. The platform housing the transmission technology is much smaller and more compact than before. Until now, these plants have been connected to the grid via large central converter platforms. Siemens is now further developing the transmission technology, enabling a large number of much smaller platforms to be built. With the new solution, a direct-current cable can connect several of these platforms sequentially in a wind farm and then route them to an onshore transformer substation. Overall, this solution costs less and is also more efficient than the approach used with conventional platforms.	https://www.siemens.com/press/PR2015100358EMEN
• In January 2016, the H2020 project named "PROMOTioN - Progress on Meshed HVDC Offshore Transmission Networks" was started with a number of international industrial and academic participants. Part of the project will be the development and demonstration of an HVDC grid protection system which utilises multi-vendor methods within the full scale Multi-Terminal Test Environment. The multi-vendor approach will allow DC grid protection to become a “plug-and-play” solution. Another technology pathway will first time demonstrate performance of existing HVDC circuit breaker prototypes to provide confidence and demonstrate technology readiness of this crucial network component. The additional pathway will develop the international regulatory and financial framework, essential for funding, deployment and operation of meshed offshore HVDC grids.	http://cordis.europa.eu/project/rcn/199016_en.html

• As part of the HubNet (The Supergen Energy Networks Hub) Position Paper Series, a report was published on 05/05/16 titled "Planning and Operation of the North Sea Grid". The report mentions that Scottish Hydro Electric Transmission in collaboration with other Transmission Owners (i.e. National Grid and Scottish Power), will build a Multi-Terminal Test Environment (MTTE) for HVDC systems by 2017. This facility will combine real time simulators with physical HVDC control panels to test the compatibility of the control and protection systems provided by different manufacturers. In Europe, 39 partners from 11 countries are working on the BEST PATHS project to develop five demos consisting of full scale experiments and pilot projects to remove existing barriers to multi-terminal HVDC grids by 2018. The experimental results will be integrated into the European impact analyses and form the basis for development of the proposed North Sea grid.	http://www.hubnet.org.uk/filebyid/790/NorthSeaGrid.pdf
• In 11/10/16, Mitsubishi Electric Corporation (TOKYO:6503) announced today that it will enter the global market for voltage-sourced converters (VSC) based high-voltage direct current (HVDC) systems with a new HVDC verification facility to be built at its Transmission and Distribution Center in Amagasaki, Japan by 2018. The company is targeting more than $500 million in global orders for HVDC -Diamond® systems by 2020. HVDC-Diamond® systems will utilize the company's own high-voltage insulated gate bipolar transistors (HVIGBT). HVIGBT devices are insulated for high voltage and designed for large current ratings to reduce the number of sub-modules, resulting in space and cost savings.	http://news.sys-con.com/node/3930650

27.4 Additional comments

None for this indicator

27.5 Recommendations

None for this indicator

28 Lifting conditions for blades

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Turbines	Lifting conditions for blades

28.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 as there is significant evidence from engagement that the 2020 target for this indicator has already been comfortably achieved, even for projects deploying the largest blades for contemporary 6-8 MW turbines.

Last year this indicator was also assessed as ahead of target, again noting that targets for future years had already been comfortably achieved.

Technology innovation in lifting equipment has been a strong contributing factor to the steady increase in workable wind speed limits, although there is also a thread throughout evidence suggesting that at least some of the progress in this area has been achieved as a result of increased levels of experience, both in project teams over the life of a series of similar installations but also throughout the pool of installation contractors more generally.

Outlook:

In the future it is possible that working wind speed limits will increase still further, but the drive and desire to do so beyond perhaps 14 or 15 m/s is expected to decrease, as the amount of additional time available to installation projects will diminish, and further investment to increase the limit will follow a law of diminishing returns. There were not yet significant challenges described by the supply chain in the lifting of even the largest blades currently, and as such it is expected that the next iteration of current blade designs will still be installable. Challenges other than blade lifting (including handling and storage on deck) may present as much of a challenge for installation teams if blade size was to increase towards 100 m.

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, supporting the fact that even the largest blades are already being installed at close to the targets required for ‘on target’ cost reduction in 2020.

28.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	9.75 m/s	10.5 m/s	11 m/s	12 m/s	12.5 m/s
On target	9 m/s	9.75 m/s	10.5 m/s	11 m/s	12 m/s
Behind target	8.5 m/s	9 m/s	9.75 m/s	10.5 m/s	11 m/s
Missed target	Operational experience with current practice	8 m/s	9 m/s	10 m/s	10.5 m/s

	proves worse than expected, especially with larger blades.				

28.3 Evidence

28.3.1 Questionnaires

Category	Questionnaire response
What wind speed (m/s) do you think the industry can currently install blades at?	
[WTG OEM]	10
[WTG OEM]	Currently 12 m/s.
[WTG OEM]	12 m/s
[Installation]	Can? Or Allowed? I believe that up to 16 m/s is feasible
[Developer]	12 m/s

[Developer]	10-12 m/s (10 minute average) @ 100 m LAT for single blade installation
Discuss any initiatives you are aware of that aim to increase this limit.	
[WTG OEM]	The BoomLock concept from DEME
[WTG OEM]	Solutions available for 13/14 m/s through improved blade lifting yokes etc.
[WTG OEM]	Confidentiality considerations
[Installation]	Design of Tools, Tag lines, and devices to hold or restrain Crane hooks, and Blade tools.
[Developer]	Most blade lifting tools today are designed for wind speed higher than 12 m/s, but only used up to 12 m/s
[Developer]	Improved blade installation tools, boom-cable movement restrainers for the cranes (e.g. boom-lock)
How will it improve over the next three years?	
[WTG OEM]	Increase blade installation speeds to up to 15 m/s

[WTG OEM]	Adoption of new equipment techniques will allow lifts up to 14 m/s
[WTG OEM]	H&S always a priority, but increased experience will allow for site specific optimization.
[Installation]	Advances in 'intelligent' restraints.
[Developer]	Probably, up to a limit.
What are the largest blades you have installed within these limits to date? Do you expect this to change for future projects?	
[Installation]	14m/s, Yes
[Developer]	59 m blades has successfully been installed up to 12 m/s. As tools for blade installation are being improved is it realistic to expect that the limit will be higher in the future.
[Developer]	Blades of the commercial WTG models. This dimensions are expected to increase with the new, more powerful, WTGs being marketed.
If there is a range then please provide details.	
[Installation]	10-14 m/s, the type and direction of the wind is relevant.

[Developer]	14-15 m/s
[Developer]	n/a

28.3.2 Interview

Category	Interview response
What wind speed (m/s) do you think the industry can currently install blades at now?	
[Installation]	Blade transport and installation is as much a packaging issue as blades get larger, packaging the length and volume that they take up on deck for vessels is as big a challenge as the lifting and weather limits, for which there are already tools and controls developed to improve crane operations.
What are the largest blades you have installed within these limits to date? Do you expect this to change for future projects? If there is a range then please provide details.	
[Developer]	Not much experience in this area [on the call], not much to add.

28.3.3 Market intelligence

Evidence	Source

None for this indicator	

28.4 Additional comments

None for this indicator

28.5 Recommendations

None for this indicator

29 Feeder vessels

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Turbines	Feeder vessels

29.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Missed target	↓	Medium confidence

Finding: Missed target

Marked as ‘missed target’ for 2016 because engagement consistently suggested that the feeder vessel concept (for turbine installation) was either not necessary or not viable. It is highly unlikely that this technique will see application on any projects before 2020 and there is no evidence of intentions to design or place orders for this type of vessel.

In CRMF 2015 this indicator was assessed as ‘behind target’ noting that although considered by some developers the use of vessels in a feeder role or orders for bespoke new vessels was not evident.

When considering why the requirement foreseen in CRP for new feeder vessels (as suggested by this indicator) has not materialised there are a number of factors that may have had an influence:

- The anticipated technology development and a move to turbine installation from bespoke new floating DP vessels has not materialised, turbines are overwhelmingly still installed in the 'conventional' way from medium to large sized jack up vessels;
- Technology has not delivered a workable solution to enable offshore ship to ship transfer of large components such that a floating feeder could work with a fixed jack up vessel;
- The use of a feeder vessel would place significant weather limits on the offshore operations, which would present a programme risk;
- Perhaps the most dominant of all influences is that across the board vessel day rates have been described to have decreased significantly, with all but the most specialist installation vessels likely to be considerably cheaper now than was anticipated by CRP. This means that the economics of installation projects have changed significantly.

Outlook:

The investment in any vessel which will be specifically tied to (and depend for its income and pay-back) on the offshore wind construction industry will always require careful consideration by a potential vessel owner. However considering the current vessel market it is likely that such an investment would look particularly un-attractive.

A 'medium confidence' was expressed by industry in the outlook for this indicator, although it should be noted that the score was close to that of 'low confidence'. The outlook score reflects the view of the industry that adoption of feeder vessels for a significant portion of installation projects by 2020 is unlikely.

29.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	First feeder vessel under construction, demonstrating that	First feeder vessel delivered, demonstrating that	At least one project achieves operational benefit by using	Feeder vessels have a significant market share for the	Feeder vessels proven, 100% market share for

	technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	feeder vessels, offshore ship to ship transfer of turbines is proven and known to be operating effectively.	farthest/deepest sites. Offshore ship to ship transfer of turbines is proven and known to be operating effectively.	farthest/deepest sites with some use on nearer-shore sites.
On target	First feeder vessel ordered, demonstrating that technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	First feeder vessel under construction, demonstrating that technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	First feeder vessel delivered, demonstrating that technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	At least one project achieves operational benefit by using feeder vessels, offshore ship to ship transfer of turbines is proven and known to be operating effectively.	Feeder vessels have a significant market share for the farthest/deepest sites. Offshore ship to ship transfer of turbines is proven and known to be operating effectively.
Behind target	Considered in FEED studies and vessel design and technology to enable offshore ship to ship transfer of major turbine components emerging	First feeder vessel ordered, demonstrating that technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	First feeder vessel under construction, demonstrating that technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	First feeder vessel delivered, demonstrating that technology constraints of offshore transfer of component from a floating feeder vessel to installation vessel are starting to be addressed.	At least one project achieves operational benefit by using feeder vessels, offshore ship to ship transfer of turbines is proven and known to be operating effectively.

Missed target	No designs or consideration in FEED studies	No designs or consideration in FEED studies	One feeder vessel ordered	First feeder vessel under construction	First feeder vessel delivered

29.3 Evidence

29.3.1 Questionnaires

Category	Questionnaire response
For far-shore (>~70km) wind farms that you are involved with, are you considering in FEED the use of fast feeder vessels to transport parts to site. Specifically, are you considering strategies which require offshore ship-to-ship transfer of major components?	
[WTG OEM]	Yes
[WTG OEM]	No - Whilst having primary installation vessel steaming in and out of port appears inefficient still the best way to install.
[WTG OEM]	Confidentiality considerations
[Installation]	No

[Installation]	Yes
[Developer]	Feeder vessels is always considered as an alternative.
[Developer]	Modes of offshore transfer are being considered, although not very sophisticated, e.g. transfer from barges to the installation vessel.
Discuss any barriers to this approach, and whether you expect them to change in the next few years.	
[WTG OEM]	Floating lifts are currently limited by crane capacity and dynamic motion of the vessels. The sea states thus heavily influence the carrying capacity and hence what components can be transferred
[WTG OEM]	No -
[WTG OEM]	Technical/Economical still uncertain
[Installation]	Limitations in Transfer environmental conditions will make the overall concept unbeneficial, when factoring a further vessel(s). Alternatively, the cost of a vessel that can counter the environment (i.e. almost a WTIV in itself) may as well install, for the day rates it would command.
[Installation]	Ship to Ship transfer is a tricky operation - due to the exponential movement compensation required in terms of e.g. craneage. However the Siem Moxie has successfully performed Ship to Ship transfers on a recent project of key tools and

	equipment - meaning that in due course she will be able to remain offshore even longer, reducing the overall construction program further.
[Developer]	Weather conditions are a barrier, in particular ship to ship transfer of components.
[Developer]	The typical barriers are reduced workability and lack of clear convenience when compared to hubs at ports. Both things can change for project specific logistic setups (distance to the closer port and to the manufacturing site)
Describe your strategy for optimising major component (e.g. foundations, turbines) logistics.	
[WTG OEM]	We use a just-in-time strategy to transport the turbine components
[WTG OEM]	Lift it as little as possible.. Nacelles will only have two lifts produced in factory in DE or DK and Ro-ro to port, vessel and assembly harbour. Lifted once onto vessel and the once onto tower. Specialist vessels and providers moving components to assembly harbour
[WTG OEM]	Project specific logistics strategy, benefiting from industry experience and own lessons learned. Industrial clusters. Improved deployment of purpose specific tools

[Installation]	Larger Cargo capacity to allow for volume (qty) and shorter sailing distances.
[Developer]	Strategy is project specific so will be adapted on a site specific basis
[Developer]	Use of marshalling harbours, secured by the developer when necessary or provided by the contractor if suitable.
Do you have contracts in place that allow flexibility in logistics?	
[WTG OEM]	Yes
[WTG OEM]	Yes
[WTG OEM]	Yes
[Installation]	No
[Installation]	Yes
[Developer]	No

Are you aware of any vessels on the market (or on order) that would be expected to specifically occupy this role? If so please provide details.	
[WTG OEM]	No
[WTG OEM]	[link to press release]
[WTG OEM]	Confidentiality considerations
[Installation]	Question is ambiguous - 'Specifically occupy the role' as a feeder vessel with efficiency? No
[Developer]	Yes there are currently a number of vessels on the market that are capable of delivering the transport and installation of components.
[Developer]	No

29.3.2 Interview

Category	Interview response

For far-shore (>~70km) wind farms that you are involved with, are you considering in FEED the use of fast feeder vessels to transport parts to site. Specifically, are you considering strategies which require offshore ship-to-ship transfer of major components?	
[Installation]	[Installation] completed a study investigating feeder vessel concepts for Round 3 sites on the East Coast. Feeder vessels are a more viable solution for further offshore sites such as Dogger Bank, however for projects [Installation]'s current pipeline no feeder vessel solutions are being considered.
[Installation]	One of the biggest risks of a feeder solution is that you cannot guarantee you can lift kit off a barge once the barge is offshore and in position – changes in weather conditions may result in big delays so need big weather windows. One solution that was considered for Scottish Sites was to have jack-ups coming into shallow waters and being fed by feeder vessels; some concept work has been performed to investigate this solution. This may be more feasible than doing feeding operations out in open water.
[Installation]	[Installation] have never really found a requirement for feeder vessels. There is likely insufficient speed and installation advantage to be found by using a feeder barge concept, as to have the capability to provide a stable (assumed jacked up) platform to enable a ship to ship transfer whilst offshore then the capabilities of the feeder vessel would make it too expensive to offer a significant advantage. Suspect that the economics cannot be made to stack up, evidenced by the fact that they are not seen in use.
Discuss any barriers to this approach, and whether you expect them to change in the next few years.	
[Installation]	In general, day rates for jack-up vessels are coming down so it is becoming more affordable to perform extra transits between site and port and the cost benefit of feeder vessels starts to reduce. By the time [PROJECT] begins construction

	there may be an oversupply of current class of vessels with low day rates so it may become affordable to use two jack-up vessels cycling as opposed to a feeder solution.
Describe your strategy for optimising major component (e.g. foundations, turbines) logistics.	
[Developer]	Technology has to improve to keep pace with what can be done now and evolve as turbine and foundation technology moves on.

29.3.3 Market intelligence

Evidence	Source
• In January 2016, an article of HBB Hanseatic Break Bulk, the marine logistics company with the title "FEEDER SYSTEM: “Feeder to serve for the match", highlighted the importance for HBB to develop coastal concept studies for transportation of Offshore Wind foundations and components and the advantages of feeder systems in foundation installation.	http://www.offshorewind.biz/2016/01/19/feeder-system-feeder-to-serve-for-the-match/
• In August 2016, Dutch companies CFL and Barge Master have joined forces to offer a ”feeder concept” which is said to optimise offshore logistics during wind farm installation phase and could lead to up to 40% reduction in installation time and costs, Bjorn Knopper, Commercial Manager at CFL Offshore told Offshore WIND. The concept combines CFL’s new 128 m, DP 2 multipurpose supply and feeder vessel Joint Runner 1 with Barge	http://www.offshorewind.biz/2016/08/16/cfl-and-barge-master-team-up-on-feeder-concept/

Master's T-700 motion compensated platforms fitted into the vessel's 82.5 m long cargo hold for delivery of the ever-growing wind turbine components from a port directly to an installation vessel.	
• In September 2016, the last couple of years DNV GL – Energy team have been working on a 'Fast Feeder Vessel' or FFV concept which will allow an entire set of turbine components to be unitised and rolled on multi-axle Self Propelled Modular Transporters (SPMTs) from the quay to feeder and feeder to installation vessel in one piece.	http://www.maritimejournal.com/news101/marine-renewable-energy/wind-ro-ro-with-a-twist2
• DNV GL have announced that they aim to establish a Joint Industry Project (JIP) to develop a Recommended Practice for the unitisation of project cargo based on the 'twisties' concept.	https://www.dnvgl.com/article/-dnv-gl-twisties-joint-industry-project-79081

29.4 Additional comments

None for this indicator

29.5 Recommendations

None for this indicator

30 Improvements in the installation process for monopiles through better vessels

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Support structures	Improvements in the installation process for monopiles through better vessels

30.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Missed target	Missed target	⇨	Medium confidence

Finding: Missed target

Marked as 'missed target' in 2016 because there is no evidence of any plans for orders to be placed for large new floating DP vessels capable of installing offshore wind foundations, or any designs at an advanced stage. There is no evidence suggesting that investment in new offshore construction vessels is likely.

Last year this indicator was also assessed as 'missed target' noting similarly that there was no evidence suggesting that the new vessels anticipated by CRP would be likely to materialise.

Engagement this year has suggested that for reasons of oversupply of suitable vessels, and a depressed market in offshore construction influenced by the oil and gas industry the day rates for installation vessels have generally reduced, discouraging investment in any new

vessels for the fleet of offshore wind foundation installation vessels. There are some exceptions to this, where, for example the number of available vessels capable of installing the largest (>1000 t) foundations is small, with one new jack up installation vessel delivered in 2015.

Outlook:

For at least the near future there is anticipated to be sufficient supply in the market of available vessels to install monopile foundations for most projects. Suitable installation vessel availability for the largest monopiles may be slightly more competitive, but there is not at present evidence to suggest that the volume of installation work available significantly exceeds the capability of the fleet of currently available vessels to supply.

This indicator specifically seeks to track developments in the design and build of new installation vessels and development of installation techniques. For at least the medium term it is not anticipated that there will be significant advancements in either installation methodologies or new vessels; business as usual is expected.

Finally, whilst this indicators status and outlook may suggest that cost reduction has not been achieved, it may not be as negative as suggested. Competition and capabilities of the current vessel fleet is likely driving cost reduction (as described in other indicators) and the lack of a requirement for new vessels is directly related to the current expected pipeline of construction projects, which is lower than was expected in the past.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, reflecting the fact that although new vessels have been slow to materialise, the industry does not see a significant barrier to cost reduction imposed by the capabilities of the current fleet.

30.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Purpose built vessels able to install largest	Purpose built vessels able to install largest	Isolated use of non-purpose built	Range of purpose built foundation installation vessels	Range of purpose built foundation installation vessels

	monopiles available to market. A quarter of projects still using converted vessels.	monopiles available to market. A quarter of projects still using converted vessels.	foundation installation vessels.	capable of installing largest monopiles have 100% of market, includes floating DP vessels.	capable of installing largest monopiles have 100% of market, includes floating DP vessels.
On target	Purpose built vessels capable of installing largest turbines on order or modifications to existing cranes and hammers ongoing.	Purpose built vessels able to install largest monopiles available to market. A quarter of projects still using converted vessels.	Purpose built vessels able to install largest monopiles available to market. A quarter of projects still using converted vessels.	Isolated use of non-purpose built foundation installation vessels.	Range of purpose built foundation installation vessels capable of installing largest monopiles have 100% of market, includes floating DP vessels.
Behind target	New purpose built floating DP vessels for monopile installation on the market, with around half of projects using converted vessel types. Installation trials of 12m monopiles underway	Purpose built vessels capable of installing largest turbines on order or modifications to existing cranes and hammers ongoing.	Purpose built vessels able to install largest monopiles available to market. A quarter of projects still using converted vessels.	Purpose built vessels able to install largest monopiles available to market. A quarter of projects still using converted vessels.	Isolated use of non-purpose built foundation installation vessels.
Missed target	Slow introduction of new vessels, with significant teething issues and no increase in Hs. No designs for larger vessels being developed.	New purpose built floating DP vessels for monopile installation on the market, with around half of projects using converted vessel types. Installation	Purpose built vessels capable of installing largest turbines on order or modifications to existing cranes and hammers ongoing.	Purpose built vessels able to install largest monopiles available to market. A quarter of projects still using converted vessels.	Purpose built vessels able to install largest monopiles available to market. A quarter of projects still using converted vessels.

		trials of 12m monopiles underway			

30.3 Evidence

30.3.1 Questionnaires

Category	Questionnaire response
What type of vessel are you considering for monopile installation on your next or future projects?	
Designer / Survey	N/A
[Installation]	Conventional WTIV / Jack Up Vessel
[Foundation]	Heavy-Lift Jack-up vessels
[Developer]	Heavy lift vessels all of which have been utilised in the industry on previous offshore projects.
[Developer]	Jack up and DP2 Vessels
Are you aware of any designs, orders, or plans to bring new foundation installation vessels to market in the next 5 years?	

Designer / Survey	N/A
[Installation]	Designs - there are many. Orders or commitments to build - no.
[Foundation]	No input
[Installation]	Just what I read in the news or saw at conferences, including [COMPANY], a few [LOCATION] companies etc.
[Developer]	Yes
[Developer]	Yes, although some new build projects might have been suspended due to insufficient confidence in the future of the sector (or lack of contracts in place).
Discuss whether you think the current fleet of available foundation installation vessels is likely to offer optimum capability for your project(s).	
Designer / Survey	N/A
[Installation]	No - Increased WTG weights and heights required, blade lengths and foundation designs planned for the coming 5 years will give the industry a short fall in high end vessels (again)

[Foundation]	Short answer is yes.
[Developer]	In the near term yes.
[Developer]	The current fleet does not offer a good competitive environment for the increasing water depth of some new projects. In many cases it is suitable, but not in enough number to bring costs down.
Please describe how you think installation vessel technology may change in the next 5 years.	
Designer / Survey	I would expect the installation methods to be less crane dependent, reduce offshore operations.
[Installation]	A potential for technology to remove environmental effects of vessel movement at the crane hook
[Installation]	In my personal opinion we need to move away from jack-ups all together. By trying to create an artificial "onshore environment" we are not addressing the root-cause of the challenges surrounding installations offshore. The sooner we accept that we need to avoid heavy lifts offshore wherever possible, the better.
[Developer]	Innovative solutions are ongoing with suppliers, for example vibro coring, suction based foundations and accuracy of pile driving. There are continuous improvements and changes in design to improve safety measures to reduce time offshore and increase integrity of asset
[Developer]	Most of the existing fleet would have completed crane upgrades. Also some efficiency aspects will be improved, e.g. workability via technology and by validation/certification based on trials.

30.3.2 Interview

Category	Interview response
What type of vessel are you considering for monopile installation on your next or future projects?	
[Installation]	[Installation] have not completed any foundation installation projects for 3 years, they are not the focus for the company.
Are you aware of any designs, orders, or plans to bring new foundation installation vessels to market in the next 5 years?	
[Installation]	[Installation] have [the ability to] put leg extensions on jack-up vessels and are awaiting a relevant project to use them and justify the cost. The capability of current vessels are optimised for the current size of turbine [installation]. Until the industry progresses to 10 MW+ turbines, it is unlikely that XXL jack-up vessels will be required [for turbine installation].
Discuss whether you think the current fleet of available foundation installation vessels is likely to offer optimum capability for your project(s).	
[Installation]	For weight and size reasons, the company is focussed on turbine installation. There was one potential missed opportunity when some projects that were expected to involve very heavy monopiles ended up with lighter designs, which could have been accommodated by [Installation] vessels.
[Foundation]	For XL monopiles there are only 2-3 installation vessels that can lift the very large monopiles and these already command a premium. When the market gets tighter again for large installation vessels this could have a further cost impact.

[Foundation]	Open question, when move from conventional monopile 1000 t – to 1500 t + with large turbine does the performance and installation continue to be business as usual or not? What challenges are there around XL monopiles, when going ever bigger there may be future challenges?
Please describe how you think installation vessel technology may change in the next 5 years.	
[Installation]	The lighter [than originally anticipated] foundation designs were potentially attributed to improved designs, changing of standards or improved volume and quality of data on soil conditions.
[Foundation]	No change expected.
[Developer]	Better planning tools, taking account of previous learnings and more extensive data, e.g. weather Becoming more experienced with respect to installation as a result of a predictable pipeline of projects across countries and limited periods of demobilisation (and therefore subsequent re-skilling)

30.3.3 Market intelligence

Evidence	Source
• In November 2015, Wind Energy Update's Offshore Foundations and Supporting Structures Report 2015 was published highlighting that the European offshore wind industry has a fleet of more than 75 vessels to support it, but almost half of the jack-up vessels in use are not capable of installing 8 MW turbines now planned for some projects and are not equipped to handle deep-water monopile installations. Developers continue to convert	http://www.windpowerengineering.com/construction/offshore-projects-face-

existing vessels not originally designed to handle the new higher-capacity structures, while uncertainty over the regulatory support for future offshore wind growth slows the development of new purpose-built vessels. Currently only around a dozen vessels are fully adapted for work in the offshore wind industry, the report said, and only seven in the world are capable of handling monopiles weighing more than 1,000 tonnes. Shipbuilders are responding to the demand for purpose-built installation vessels with a new generation of ships designed specifically for offshore wind, including jack-up vessels that follow guidelines set out by the certification body DNV GL in 2010. Compared to existing vessels used in the wind sector, these ships have faster jacking speeds and the ability to operate in deeper waters, up to depths of 60 m with a jack up 15 m above sea level. In addition, these and other, free-floating, vessels are larger than many of the ships currently in service, typically with accommodation for more than 100 people, and have dynamic positioning capabilities along with greater deck space and storage capacity. The new purpose built vessels are also faster and more able to handle adverse weather conditions. This makes them more suited for the installation of XL monopiles required for larger turbines in greater depths further out to sea. Examples of this new generation of vessels include W3GMarine's OWTIS, with 4,500 m² of free deck space and a lifting capacity of up to 1,500 tons or Vuyk Engineering's Vuyk VVV, with 4,700 m² of deck space and 3,000 tonnes lifting capacity.	vessel-shortage-for-large-turbines-until-2018/
• On 04/03/16 UK offshore construction contractor Seajacks International has inaugurated its fifth self-propelled jack-up vessel, the $250m Scylla – the largest wind turbine installation vessel yet developed by the industry – at the English east coast port of Great Yarmouth. The giant self-propelled jack-up vessel is designed to install the next generation of 7 MW and 8 MW wind turbines, jacket foundations, and so-called XL monopiles weighting up to 1,300 tonnes. Scylla's first assignment will be in German waters where it is due to start installing the first of 67 XL monopiles at Highland Group's 400 MW Veja Mate offshore wind farm in mid-March.	http://www.rechargenews.com/wind/1425958/seajacks-has-designs-on-ea1-as-largest-wiv-scylla-enters-service
• In August 2016, Swire Blue Ocean jack-up Pacific Orca and MPI vessel Discovery have completed a total of 52 of the 116 Sif-made monopiles at Rampion. Both vessels will continue the foundation campaign for the remainder of the year with the erection of 116 MHI Vestas V112-3.45 MW turbines due to start in early 2017.	http://renews.biz/103906/rampion-

	nears-monopile-milestone/
• In June 2016, a Recharge article touched the issue of the limited supply of capable vessels (only ten) to install the biggest turbines available to developers and their large foundations. The giant Seajacks' 23,000 tonne self-propelled Scylla jack-up is designed to install 7-8 MW turbines, jacket foundations, and so-called XL monopiles weighing up to 1,300 tonnes. The company also has designs on the table for an additional jack-up, similar in size to Scylla but with even greater lifting capacity. Norwegian contractor Fred Olsen Windcarrier has completed a major upgrade of its Brave Tern jack-up at the Franklin Offshore yard in Rotterdam, carrying out modifications so it can install larger turbines in water depths of up to 60 m. Denmark's A2Sea has outlined plans to restructure its business, concentrating on its newer bigger vessels — the Sea Challenger and Sea Installer, which have recently had their crane booms extended to support 7-8 MW turbines — while taking some of the older jack-ups out of its fleet earlier this year. The Sea Challenger will support the commissioning of the transformer station at Statoil's 402 MW Dudgeon from August. MAKE Consulting forecasts that purpose-built jack-up vessels with lifting capacities of up to 1,500 tonnes and free deck space of up to 6,000 m^2 will be needed to avoid capacity constraints post-2020.	http://webcache.googleusercontent.com/search?q=cache:p8Itk6avMWUJ:www.rechargenews.com/wind/1433596/where-installation-vessels-are-concerned-the-bigger-the-better+&cd=1&hl=en&ct=clnk&gl=uk
• In September 2016, Fugro highlighted a selection of recent innovations at WindEnergy Hamburg in Germany that reduce costs and improve efficiency in the development of offshore wind farms. Among them were the 3Direct real-time precise jacket and foundation positioning system and Fugro OARS centralised positioning support for offshore installations. 3Direct uses vision-based technology to track the position of monopile and jacket components during installation. Using high-resolution, digital video cameras on the construction vessel the position, elevation, inclination and heading of structures can be constantly determined and monitored. Fugro OARS (Office Assisted Remote Services), is a service that eliminates the need for specialist teams to be present on vessels during offshore installations. Global OARS command centres are manned by Fugro's qualified surveyors who are available to conduct survey tasks as though they were physically on board the vessel.	https://www.hydro-international.com/content/news/fugro-focuses-on-innovation-at-wind-energy

30.4 Additional comments

None for this indicator

30.5 Recommendations

None for this indicator

31 Improvements in operational weather windows for monopile installation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Support structures	Improvements in operational weather windows for monopile installation

31.1 Summary Analysis

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

Finding: Ahead of target

Marked as ahead of target in 2016 because engagement suggests that wave height limits of 2.0 m Hs is widely considered to be achievable.

Last year this indicator was also assessed as ‘ahead of target’ noting that at that time a target of 1.7 m Hs had been met and likely exceeded on certain projects.

It does not appear that the increasing size of monopile foundations is presenting a significant challenge to installations, although the handling (e.g. pile gripper) operations associated with heavy foundations and splash zone entry may eventually limit a gradual increase in operating weather limits.

Outlook:

A natural gradual progression associated with learning and experience on both individual projects and over the installation industry as a whole does look likely to continue to allow weather limits to increase in the near future. However, further significant advances would require investment in new vessels and/or technology, which at present looks unlikely. Finally, diminishing returns may be available in terms of installation programmes by seeking to add significant capability beyond 2.5 m Hs, which could also serve to dis-incentivise efforts to substantially increase installation capabilities.

A 'high confidence' in the outlook for this indicator was expressed by the industry, reflecting confidence in the technology pathway enabling weather limits to tend to gradually increase towards at least the 2020 target of 2.5 m Hs.

31.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Operational wave height limited to Hs = 1.9 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit. New tooling and techniques in use and demonstrating no limitation for installing even	Operational wave height limited to Hs = 2.1 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit. New tooling and techniques in use and demonstrating no limitation for installing even	Operational wave height limited to Hs = 2.3 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit. New tooling and techniques in use and demonstrating no limitation for installing even	Operational wave height limited to Hs = 2.5 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit. New tooling and techniques in use and demonstrating no limitation for installing even	Operational wave height limited to Hs = 2.5 m for most sensitive installation operations as standard, with majority of monopile installation tasks conducted safely beyond this limit. New tooling and techniques in use and demonstrating no limitation for installing even

	largest XL monopiles.	largest XL monopiles.	largest XL monopiles.	largest XL monopiles.	largest XL monopiles, with tooling for virtually unlimited operation available if necessary.
On target	Operational wave height limited to Hs = 1.7 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit.	Operational wave height limited to Hs = 1.9 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit.	Operational wave height limited to Hs = 2.1 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit.	Operational wave height limited to Hs = 2.3 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit.	Operational wave height limited to Hs = 2.5 m for most sensitive installation operations, with majority of monopile installation tasks conducted safely beyond this limit.
Behind target	Operational wave height limited to Hs = 1.5 m for majority of installation operations, with majority of monopile installation tasks conducted below this limit.	Operational wave height limited to Hs = 1.7 m for majority of installation operations, with majority of monopile installation tasks conducted below this limit.	Operational wave height limited to Hs = 1.9 m for majority of installation operations, with majority of monopile installation tasks conducted below this limit.	Operational wave height limited to Hs = 2.1 m for majority of installation operations, with majority of monopile installation tasks conducted below this limit.	Operational wave height limited to Hs = 2.3 m for majority of installation operations, with majority of monopile installation tasks conducted below this limit.
Missed target	Operational wave height limited to Hs = 1.4 m for majority of installation operations, with majority of monopile installation tasks	Operational wave height limited to Hs = 1.5 m for majority of installation operations, with majority of monopile installation tasks	Operational wave height limited to Hs = 1.6 m for majority of installation operations, with majority of monopile installation tasks	Operational wave height limited to Hs = 1.7 m for majority of installation operations, with majority of monopile installation tasks	Operational wave height limited to Hs = 1.8 m for majority of installation operations, with majority of monopile installation tasks

	conducted below this limit.	conducted below this limit.	conducted below this limit.	conducted below this limit.	conducted below this limit.

31.3 Evidence

31.3.1 Questionnaires

Category	Questionnaire response
What is the operational weather window (m Hs) that you would consider reasonable for installation now for jack up vessels to install monopiles?	
[Installation]	For clarity - do you mean to jack up in field? - 2.5 m Hs, or to lift and install Monopiles? 2.0m Hs
[Developer]	Largely dependent on the vessel and its equipment, circa 2 m Hs
[Developer]	Hs of at least 1.5 m, and 2.0 m in most cases
Are you aware of plans to significantly increase in the future? If so, what is required?	
[Installation]	Vessel design for jacking increases. Installation tools and crane capacity to allow for the DAF Factor
[Developer]	Increase weather window however consideration to safety, equipment, personnel dependant.

[Developer]	There are some plans, but not for significantly more than 2.0 m.
Discuss what other influences limit operating conditions for installation of monopiles? (e.g. wave height limits for different parts of the operation, wind conditions, size of foundations)	
[Installation]	Period and direction of wave. Foundation design and shape. Gripper operating parameters
[Developer]	Weather restrictions on equipment, personnel
[Developer]	Current speed is important in some projects.
Please detail how you think this may change over the next five years.	
[Installation]	It will change as foundation designs change to suit the larger WTG and Water depths.
[Developer]	Provisions to reduce time offshore, i.e. fitting and testing onshore
[Developer]	More experience working in intense metocean conditions, and the motivation to reduce costs, will help to improve operational limits.

31.3.2 Interview

Category	Interview response
Are you aware of plans to significantly increase in the future? If so, what is required?	
[Installation]	From a wind and wave perspective, [Installation] have been operating under the same limits and parameters for the last 3 years so the vessels are not developing in that sense. Instead [Installation] are pushing the weights and carrying capacity of what the current vessels can accommodate in order to meet the demand for larger installation of larger turbines.
Discuss what other influences limit operating conditions for installation of monopiles? (e.g. wave height limits for different parts of the operation, wind conditions, size of foundations)	
[Foundation]	Monopiles have smart kit (which is expensive) which have shown big improvements in speed of installation, how much remains for further reduction in time required?
Please detail how you think this may change over the next five years.	
[Installation]	The biggest challenge is to make sure the current class of vessel that they operate is capable of installing the current class of large turbines. There are less changes occurring on dynamic positioning upgrades, which may be required for the next generation of turbine, there is currently more benefit in increasing the capacity of vessels to carry more weight
[Developer]	Better planning tools, taking account of previous learnings and more extensive data, e.g. weather

	Becoming more experienced with respect to installation as a result of a predictable pipeline of projects across countries and limited periods of demobilisation (and therefore subsequent re-skilling)

31.3.3 Market intelligence

Evidence	Source
None for this indicator	

31.4 Additional comments

None for this indicator

31.5 Recommendations

None for this indicator

32 Purpose built jacket installation vessels

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Support structures	Purpose built jacket installation vessels

32.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Missed target	↓	▪ Low confidence

Finding: Missed target

Marked as 'missed target' in 2016 because there is no evidence of new vessels being ordered for offshore wind foundation installation, and projects have yet to be delivered with installation vessels carrying more than 3 – 4 jacket foundations simultaneously.

Last year this indicator was assessed as 'behind target' noting a limited supply of vessels capable of carrying multiple jacket foundations and/or operating in deeper (40 m+) water where jackets tend to be deployed.

The new floating DP installation vessels anticipated to be required by CRP have not materialised. This may be partly due to the reduced pipeline of projects demanding jacket installation vessels. The market day rates for offshore construction vessels and the uncertain pipeline of jacket installation projects in the longer term appear to have discouraged any investment decisions in new installation vessels.

Outlook:

With the continued increase in the size of turbines used on contemporary projects (installation work in 2016 still included projects using 4 MW class machines) it is possible that the upper end of the market in installation vessels will see something of a tightening of competition in the coming years.

There is not yet evidence to suggest that projects will be delayed or challenged by a lack of vessels, in coming years there could be a situation where projects will be forced to use vessels that are available rather than the vessel which may necessarily be optimum for their individual requirements, a particular challenge remains around the availability of jack up vessels capable of installing jackets in deeper water which could see more use of floating/barge/shear-leg type vessels for these projects.

A 'low confidence' outlook for this indicator was expressed by industry. Reflecting an expectation that new DP jacket installation vessels look unlikely to be ordered before 2020. This may or may not represent a barrier to cost reduction, as in many cases it was felt that sufficient capabilities existed in the current fleet of installation vessels.

32.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	At least one more large floating DP vessels ordered able to carry 6 jackets for 6 MW turbines	New large floating DP vessels commissioned and successfully completes first season of installation	Second large floating DP vessels commissioned and successfully completes first season of installation. First large vessel operating well.	Large floating DP vessels able to take around six jackets for 6 MW class turbines used by over half of projects constructed this year	New large floating DP vessels capable of carrying 6 times 6 MW jackets used for 80% of jacket installations

On target	Large floating DP vessel ordered able to take 6 x 6 MW jackets	At least one more large floating DP vessels ordered able to carry 6 jackets for 6 MW turbines	New large floating DP vessels commissioned and successfully completes first season of installation	Second large floating DP vessels commissioned and successfully completes first season of installation. First large vessel operating well.	Large floating DP vessels able to take around six jackets for 6 MW class turbines used by over half of projects constructed this year
Behind target	Designs for large floating DP vessels well progressed. Ongoing installation using vessels which can carry 4 jackets suitable for 6 MW turbines	Large floating DP vessel ordered able to take 6 x 6 MW jackets	At least one more large floating DP vessels ordered able to carry 6 jackets for 6 MW turbines	New large floating DP vessels commissioned and successfully completes first season of installation	Second large floating DP vessels commissioned and successfully completes first season of installation. First large vessel operating well.
Missed target	Only vessels available are able to take 3 jackets suitable for 6 MW turbines	Designs for large floating DP vessels well progressed. Ongoing installation using vessels which can carry 4 jackets suitable for 6 MW turbines	Only one large floating DP vessel ordered able to take 6 x 6 MW jackets	At least one more large floating DP vessels ordered able to carry 6 jackets for 6 MW turbines	New large floating DP vessels commissioned and successfully completes first season of installation

32.3 Evidence

32.3.1 Questionnaires

Category	Questionnaire response
Do you plan to charter purpose built jacket installation vessels? If so, state when supply contracts are likely to be placed.	
[Foundation]	No input
[Installation]	N/A as an Installation Contractor
[Developer]	No.
[Developer]	Some contracts may be placed in the following 4 years, and they would be installation contracts, rather than purely charters.
How many jackets do you expect to be carried by your chosen installation vessel? Does this change considerably for increasing turbine rated capacity?	
[Foundation]	3 to 4 jackets.
[Installation]	N/A as an Installation Contractor - we aim for 6.

[Developer]	Not applicable
[Developer]	At least 2 and preferably 4 or more, but it largely depends on the site conditions and turbine size
Do you believe that the vessel characteristics offered by the supply chain meet your current and future jacket installation needs? Please explain your answer.	
[Foundation]	Lifting capacities of several vessels are now suitable for jackets.
[Installation]	I would suggest the answer is No
[Developer]	Not applicable
[Developer]	There are options, but more vessels with more capacity are welcome to increase competition.
Do you expect to see any new purpose built jacket installation vessels coming to market in the next 5 years?	
[Foundation]	No input
[Installation]	I am curious to know! We expect to deliver one or two.
[Developer]	No

[Developer]	Probably, but some changes in the support mechanisms and tender-to-execution times to allow new builds based on signed contracts.

32.3.2 Interview

Category	Interview response
Do you plan to charter purpose built jacket vessels? If so, state when supply contracts are likely to be placed.	
[Installation]	As opposed to jack-up vessels, on paper floating installation DP vessels work, however designs were based on the need for jackets which hasn't materialised as expected and development in the use of monopiles in deeper waters means the market can currently rely on existing floating crane vessels utilised in the oil and gas sector, therefore no additional investment is currently needed.
How many jackets do you expect to be carried by your chosen installation vessel? Does this change considerably for increasing turbine rated capacity?	
[Installation]	Jacket design, footprint and use of suction buckets has a big influence on the vessel design/choice and crane weight/choice.
Do you believe that the vessel characteristics offered by the supply chain meet your current and future jacket installation needs? Please explain your answer.	

[Installation]	Installation of jacket designs incorporating suction buckets is a big challenge to find the optimised combination of vessel choice/design, crane choice/weight and stand-off distance to make those installations happen smoothly. The challenge is whether you do your suction bucket jacket design first and specification before you specify the requirements of the vessel. The optimum situation would be to do them in iteration with each other, but if you do so you need to ensure the required vessel will be available for that jacket design – it is quite a complex process.
[Foundation]	Developers may see jacket installation (pre pile or post pile) as a risk, e.g. [PROJECT] have been having installation difficulties, which does not give confidence, the process of installing jackets is much less mature and hence much less certain.
Do you expect to see any new purpose built jacket installation vessels coming to market in the next 5 years?	
[Installation]	Much exists in marketing material and 'on paper' designs for concepts in installation vessels away from the classic 4 or 6 legged jack up, but there has not yet been evidence of the industry seeing the need to go this way, and no order have been placed or steel cut. [Installation] have spent about 3 million so far on tank test and design of a new vessel, with a capacity to take 5 of a current generation of turbine jacket foundation. Taking [PROJECT] as an example, jacket installation would only generate around 5 months of income, which is insufficient to validate or justify the investment decision in a new vessel on its own. We have now got to the point where offshore wind may not need much support from the public sector, this could allow developers to build whatever size of project they want, expect that when and if some larger 'subsidy free' projects can exist then there may be another step change in the cost of energy as everything about a project, including installation, can be optimised for LCOE and not just optimised for the CfD process.

	As a vessel owner, [Installation] designed and built last generations of vessels, which at the time looked overly large, but actually found that only 5 years in they required extension of capabilities to remain relevant. From a vessel owner point of view, decision of when to invest is as much about having certainty that your vessel will remain relevant, maybe less dependent now on pipeline, as a reasonably (i.e. at least flat) market is expected to continue in the medium term in European offshore wind.

32.3.3 Market intelligence

Evidence	Source
• In May 2016, the installation of the jacket foundation associated with offshore substation for the Nordsee One offshore wind farm was carried out and was installed by the floating crane vessel Rambiz 3000.	http://www.4coffshore.com/windfarms/nordsee-substation-jacket-in-place-nid3774.html
• In 2015 Jumbo Offshore has been refocusing on offshore wind from its traditional activities in offshore oil & gas. The company is expanding its traditional focus on TP installation into new areas such as pre-pile installation for jackets and jacket installations. Jumbo plans to convert its dual-crane heavy-lift vessel Fairplayer with higher cranes and a larger deck of up to 4500 m^2 to allow it to install jackets in addition to installing pre-piles and TPs. The upgraded vessel is scheduled to set sail in Q1 2018.	http://analysis.windenergyupdate.com/construction/offshore-wind-installation-vessel-capacity-tighten-after-2020

• In April 2016, Scaldis revealed the official name for their unique DP II heavy lift vessel Gulliver. During the design phase of the new DP II heavy lift vessel, Scaldis used the provisional name RAMBIZ 4000 referring to the lifting capacity. It has two Huisman cranes each with a lifting capacity of 2,000 tons, based on a design by Vuyk. The ship also has extra carrying capacity of 3,000 tons. The ship is ordered to further support and expand the services, including the installation of offshore infrastructures and decommissioning-deconstruction activities for the oil and gas industry as well as the installation of offshore wind farms, largely anticipated to be offshore substations.	http://www.scaldis-smc.com/en-GB/scaldis-reveals-official-calling-name-for-their-unique-dp-ii-heavy-lift-vessel/6/10085/ http://www.scaldis-smc.com/en-GB/construction-milestone-reached-for-the-new-build-dp-ii-heavy-lift-vessel/38/82/
• On 30/08/2016 The Hamburg based engineering & design company HeavyLift@Sea presented the advanced Floating Foundation Installation vessel concept FFI 1700 suitable for deep water installation of large monopiles, jackets and tripods. With the dimensions of 165 m length and the 43.5 m width the purpose-built FFI 1700 provides a large 130 m long, unobstructed, high strength working deck for stowing 4x XL-Monopiles up to 100 m length, 10 m diameter and 1500 t weight.	http://www.4coffshore.com/windfarms/heavylift@sea-present-new-vessel--floating-foundation-installation-vessel-ffi-1700-nid4413.html

• On 17/09/2016 Scaldis was scheduled to deploy its heavy lift vessel Rambiz to install the jacket for the 400 MW Rampion offshore wind farm's offshore substation.	http://www.offshorewind.biz/2016/09/02/rampion-set-for-flurry-of-offshore-works/
• Seaway heavy lifting have been awarded an EPCI contract for the Beatrice offshore wind farm and have stated that existing DP heavy lift vessels will be used.	https://www.seawayheavylifting.com.cy/uploads/media/Beatrice_-_final2.pdf

32.4 Additional comments

None for this indicator

32.5 Recommendations

None for this indicator

33 Flexible sea fastenings

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Support structures	Flexible sea fastenings

33.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Missed target	↓	Medium confidence

Finding: Missed target

Marked as ‘missed target’ in 2016 because engagement provided limited evidence of the application of flexible sea fastenings to jacket installation projects. There was significant evidence of designs and working practices that are enabling the re-use of sea fastenings for turbine components on WTIV, even across different WTG OEMs. Engagement suggested that stakeholders across the industry do see the application of flexible sea fastenings as offering significant cost reduction potential on jacket installation projects.

Last year this indicator was assessed as ‘behind target’ noting that the jacket installation market had to date been small, and that existing concepts for systems and/or vessels which would enable the use of flexible sea fastenings were yet to be deployed.

This indicator is intrinsically linked to the level of standardisation in jacket design and manufacture, which key industry stakeholders describe as a well understood route to cost reduction, but which for commercial reasons has yet to see significant progress.

Outlook:

At present it looks unlikely that the 2020 vision of universal application of flexible sea fastenings for jacket projects will be achieved. There is nothing at present to suggest that the dynamics and contracting can or will change sufficiently to enable the use of flexible sea fastenings for jackets. It is noteworthy that an industry JIP has been convened to further refine sea fastening of turbine components (by applying container locking concepts) but there is not yet evidence that this will have any impact on the jacket installation market.

A 'medium confidence' was expressed by industry in the outlook for this indicator. There is evidently significant remaining potential for cost reduction in sea fastening and vessel mobilisation, with industry confidence relatively low that current practice would change significantly by 2020.

33.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Flexible sea-fastenings being used by 2/3rds of jacket market	90% of jacket market uses flexible sea fastenings	90% of jacket market uses flexible sea fastenings	90% of jacket market uses flexible sea fastenings	90% of jacket market uses flexible sea fastenings
On target	Flexible sea-fastenings have been developed and are deployed on over half of jacket installation vessels	Flexible sea-fastenings being used by 2/3rds of jacket installation vessels	90% of jacket installations use flexible sea fastenings	90% of jacket market use flexible sea fastenings	All jacket installations use flexible sea fastenings

Behind target	Flexible sea-fastenings being used by quarter of the market	Flexible sea-fastenings being used by 50% of jacket market	Flexible sea-fastenings being used by 60% of jacket market	70% of jacket market uses flexible sea fastenings	80% of jacket market uses flexible sea fastenings
Missed target	Flexible sea-fastenings being used by 20% of jacket market	Flexible sea-fastenings being used by 30% of jacket market	Flexible sea-fastenings being used by 40% of jacket market	Flexible sea-fastenings being used by 50% of jacket market	Flexible sea-fastenings being used by 60% of jacket market

33.3 Evidence

33.3.1 Questionnaires

Category	Questionnaire response
If you are installing jackets, have you used flexible sea fastenings on your chosen installation vessel?	
[Foundation]	No input
Designer / Survey	N/A
[Installation]	No, but would.
[Developer]	No jackets installed

[Developer]	No
Discuss any barriers to the adoption of flexible or re-usable sea fastenings for jackets.	
[Foundation]	No input
Designer / Survey	N/A
[Installation]	None.
[Developer]	If the sea fastenings are being purchased and maintained by the vessel owner then the use of the sea fastenings across different projects may be possible. Barrier may be technical suitability
Would you be interested in cross industry collaboration to enable flexible sea fastenings to be used for jacket installation?	
[Foundation]	Yes
Designer / Survey	No
[Installation]	Yes

[Developer]	Yes
[Developer]	Yes

33.3.2 Interview

Category	Interview response
Discuss any barriers to the adoption of flexible or re-usable sea fastenings for jackets.	
[Installation]	[Installation] re-use a lot of their sea fastenings. Similar ones can be used for Vestas and [WTG OEM] turbines. They have designed fastenings to be interchangeable with adapter flanges for different turbine models. These can be used quite easily for towers, nacelles and blades but the process becomes more difficult for foundations where the design is constantly changing between projects and soil conditions, such as jackets. For these designs the fastenings would need to be more flexible that what can currently be accommodated and it would be challenging to have standard fastenings for the wide range of foundation designs.

33.3.3 Market intelligence

Evidence	Source
• The Hamburg-based design and engineering company HeavyLift@Sea GmbH said it had been contracted by MHI Vestas Offshore Wind to design grillages for the sea fastening of wind turbine blades. According to	http://www.shipandoffshore.net/news/offshore

HeavyLift@Sea, the grillages were designed to be easily installed and dismounted in order to keep the vessel flexible for alternative project transportation.	/offshore-article/id/sea-fastening-design-contract-goes-to-heavyliftsea.html
• In September 2016, Semco Maritime will be granted the assignment of fabricate and installation of new sea fastening on “Scylla”, the world’s largest vessel for installation of offshore wind turbines. That became when Semco Maritime and Scylla’s owner, Seajacks, signed the agreement for a modification of the vessel’s deck with flexible sea-fastening’s device.	http://www.scandoil.com/moxie-bm2/news/semco-maritime-to-mobilise-the-worlds-largest-vess.shtml
DNV GL have announced that they aim to establish a Joint Industry Project (JIP) to develop a Recommended Practice for the unitisation of project cargo based on the ‘twisties’ concept.	https://www.dnvgl.com/article/-dnv-gl-twisties-joint-industry-project-79081

33.4 Additional comments

None for this indicator

33.5 Recommendations

None for this indicator

34 Optimised cable pull in and hang off processes

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Cables	Optimised cable pull in and hang off processes

34.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target		Medium confidence

Finding: Ahead of target

Marked as 'ahead of target' in 2016 because there is significant evidence of continuing technology advances in cable installation, with both supply chain and developers suggesting that the current fleet of installation vessels are using processes which represent significant improvements over what was standard practice 3 – 5 years ago.

Last year this indicator was also assessed as 'ahead of target' noting that there had been deployment of next generation cable installation methodologies on at least one high profile UK cable installation project, although also noting that there had not been a large amount of cable installation work completed in 2015 compared with previous years. Using information currently available about EU projects achieving FID this year it looks likely that the requirement for 50% of projects to award contracts to contractors who will use new technologies and improved processes will be comfortably met.

Outlook:

The future outlook for this indicator remains positive. The cable installation industry has seen investment in new vessels, technology and techniques by a number of large installation contractors. As such it is expected that the majority of future installation projects will rely on what may be described as being 'next generation' installation techniques. Long term viability of all contractors will depend as in many areas on the continued visibility of a pipeline of installation projects well into the future, and there is evidence to suggest that consolidations in the installation supply chain could occur. Related to this there remains a trend for strategic partnerships between cable manufacturers and installation contractors, who see it increasingly often as necessary to offer a 'one stop shop' to developers to compete, particularly on project financed EU projects.

A 'medium confidence' was expressed by industry in the outlook for this indicator, which backs up the confidence felt by the recent investment in this area.

34.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	New cable installation processes offering improvements in time, safety or efficiency used on half of projects. New connector technologies available. First foundations installed with improved hang off technologies,	New cable installation processes offering improvements in time, safety or efficiency used on majority of projects. New connector technologies used on 1 project. New hang off techniques used on a quarter of projects.	New cable installation processes offering improvements in time, safety or efficiency become standard practice. New connector technologies used on 3 projects. New cable hang off approaches used on majority of projects	New cable installation technologies and processes offering improvements in time, safety or efficiency are standard practice. New connector technologies and hang off approaches in widespread use.	New cable installation technologies and processes offering improvements in time, safety or efficiency and new connector technologies are standard practice.

	reducing installation times.				
On target	New cable installation processes offering improvements in time, safety or efficiency used on a quarter of market.	New cable installation processes offering improvements in time, safety or efficiency used on half of projects. New connector technologies available. First foundations installed with improved hang off technologies, reducing installation times. Free hanging cables contracted by project.	New cable installation processes offering improvements in time, safety or efficiency used on majority of projects. New connector technologies used on 1 project. New hang off techniques used on a quarter of projects.	New cable installation processes offering improvements in time, safety or efficiency become standard practice. New connector technologies used on 3 projects. New cable hang off approaches used on majority of projects	New cable installation technologies and processes offering improvements in time, safety or efficiency are standard practice. New connector technologies and hang off approaches in widespread use.
Behind target	New cable installation process offering improvements in time, safety or efficiency used on 1 project. First project contracts using improved hang off techniques.	New cable installation processes offering improvements in time, safety or efficiency used on a quarter of market.	New cable installation processes offering improvements in time, safety or efficiency used on half of projects. New connector technologies available. First foundations installed with improved hang off technologies,	New cable installation processes offering improvements in time, safety or efficiency used on majority of projects. New connector technologies used on 1 project. New hang off techniques used on a quarter of projects.	New cable installation processes offering improvements in time, safety or efficiency become standard practice. New connector technologies used on 3 projects. New cable hang off approaches used on majority of projects

			reducing installation times.		
Missed target	No new designs emerging	New cable installation processes trialled	New cable installation processes offering improvements in time, safety or efficiency available. Support structure designs incorporate new hang off approaches	New cable installation process offering improvements in time, safety or efficiency used on 1 project. First project contracts using improved hang off approaches	New cable installation processes used on 30% of projects. New connector technologies available

34.3 Evidence

34.3.1 Questionnaires

Category	Questionnaire response
Describe any new approaches to cable installation or improvements to cable pull in and hang off processes that have emerged recently.	
[Installation]	Utilizing an installation or construction support vessel such as the Siem Moxie, and mobilizing multiple foundation with equipment and personnel has divorced the bottle neck during cable pull-in from the cable layer and access foundations. This has enabled a significant increase in efficiency in terms of weather capabilities but also how many cable ends can be dealt with at once. In addition to the introduction of in-line termination kits such as Pfisterers have led to a reduction in the amount of time spent performing T&T.

[Developer]	Pre-installation of CPS Involvement of the cable contractor in TP design
Are you aware of plans to develop of use new connector designs for the cable installation process?	
[Installation]	Yes
[Developer]	No
[Developer]	Yes
How do you expect cable pull in and hang off processes and equipment to change in the next few years?	
[Installation]	To a degree this will need to be considered on a case by case basis. However in some instances having pre-cut length cables with one end pre-terminated might lead to significant cost savings (however significant engineering would need to be performed around this concept before it should be trialled - and for example the cable route within the foundation is key). Also we should see an increase in the number of ISV deployed pull-in equipment - rather than looking to have kit pre-installed on every TP. This is not only more efficient in terms of cost, but actually saves time as well.
[Developer]	Expect more OWFs to move to weak link systems Expect more walk to work systems for tower teams Bigger winches as turbines and thus cables become larger, and water depths become greater

[Developer]	Optimization through development of more “plug-and-play” systems.
Discuss the level of automated assistance (unmanned operations, ROVs) in cable installation processed. Do you expect this to change in the next few years?	
[Installation]	On modern projects, for both the first end and second cable pull-ins on array cables the subsea activities are entirely without direct human intervention. Touch down monitoring during cable lay is also undertaken with ROV. It is expected that the trend continues and that, if anything, a favoring of autonomous vehicles for manipulation and surveillance of activities is to be expected.
[Developer]	Unmanned subsea operations are the ‘ALARP’ preference over subsea manned operations i.e. diving. The use of ROVs to support and enable cable installation activities means these operations are prone to the effect of sub-surface current, as such technologies that are not affected by currents will take an increasingly prominent role i.e. sonar cameras, AUV survey and inspection systems.
[Developer]	Almost entirely unmanned ROV for underwater works, and likely to increase due to increase in water depths.
Would you consider cable pull in and hang off an optimised and standardised process?	
[Installation]	No
[Developer]	No
[Developer]	Yes

34.3.2 Interview

Category	Interview response
None for this indicator	

34.3.3 Market intelligence

Evidence	Source
• On 06/11/15 Nexans Power Accessories studied the installation of subsea array cables in the offshore towers and have developed a system that gives the developer and installer certain advantages over other connection methods. By employing pre-terminated leads that utilise less expensive flexible cables, a developer may save money and an installer can save time on the preparation and testing of the medium voltage cable link between the transformer to switchgear and/or switchgear to the array cable. By using a termination point near to the hang-off rather than taking the array cable directly to the equipment, an installer may also save time on the preparation of the array cable and spend less time in the tower dealing with the inconvenience of stripping longer lengths of arrays. This results in less reliance on the weather giving a cost saving to the developer due to the implications of the Waiting on Weather charges as more work can be done onshore preparing and testing the equipment. By saving time on the installation offshore, this would in our opinion, give an earlier completion date and thereby earning the developer revenue sooner.	http://www.cablejoints.co.uk/blog/article/nexans-ojc-offshore-junction-chamber

• Vattenfall has issued a tender for the design of secondary and tertiary structures, as well as electrical outfitting on offshore wind farm foundations. The Swedish company is looking for a two-year framework agreement with as many as five operators for a total value of €4–6m, according to the tender document. Design includes items such as boat landings, ladders, platforms, railings, crane, skirts, attachments for corrosion protection systems, internal platforms and cable hang off systems, as well as interim or permanent structures for transportation or storage.	http://renews.biz/103366/vattenfall-eyes-foundations-leg-up/
• In August 2016, JDR has announced that the installation of the inter-array cables at the Nordsee One offshore wind project in Germany has been completed. JDR signed a supply contract with Siem Offshore back in April 2014 for more than 70 km of 33 kV medium voltage alternating current submarine aluminium core inter-array cables. Alongside the inter-array cables JDR was tasked with the supply of a range of accessories including cable pulling grips and hang-offs, cable cleats, power core termination connectors and fibre optic splice boxes.	http://www.4coffshore.com/windfarms/nordsee-one-array-cable-installation-completed-nid4377.html
• DNV GL has reviewed and certified Tekmar Energy's latest TekLink cable protection system (CPS) and Bellmouth accessories. It has come up with a new cable hang-off assembly that allows time saving for both temporary and permanent works, and has provided full-scale thermal testing to demonstrate the CPS is not a limiting factor for cable output performance.	http://renews.biz/103570/dnv-gl-certifies-tekmar-shield/
• ISV Siem Moxie assisted the CLV Siem Aimery with the cable pull-in, termination and testing activities deploying its offshore support units (OSU) equipped with generators, pull-in winches, tools and equipment for personnel life support at the individual offshore work sites of Nordsee One Offshore Wind Farm.	http://www.siemoffshorecontractors.com/en/news/siem-offshore-contractors-completes-inter-array-grid-cable-installation-works-of-

	the-nordsee-one-offshore-wind-farm

34.4 Additional comments

None for this indicator

34.5 Recommendations

None for this indicator

35 Improvements in operational weather limits for cables

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Cables	Improvements in operational weather limits for cables

35.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because engagement suggests that cable installations are routinely conducted in sea state limits significantly beyond the 1.6 m Hs suggested by this indicator. This can be attributed to an increased use of new purpose built vessels, improved technology and a natural learning rate through increased levels of experience in the industry. For installations still requiring use of CTV to transfer personnel it was commonly stated that the CTV to boat landing transfer of personnel is almost always the factor that influences the weather limits on cable installation tasks.

Last year this indicator was assessed as ‘on target’, noting that the limit required to be on target of 1.5 m Hs was evidenced to have been comfortably met, and that there was a clear technology pathway visible for ongoing continued increases in operating weather limits.

The fleet of cable installation vessels has expanded considerably in recent years, with designs specifically targeted at optimising the tasks associated with offshore wind cable installation displacing a previous generation of vessels which were not optimised or based on conversions of existing vessels.

Outlook:

It looks likely that the 2020 vision for this indicator will be comfortably achieved, indeed in many cases projects may already be achieving this target. Further significant increases in working conditions to beyond 3 m Hs may be technically achievable, but as with weather constraints on other installation tasks there are likely to be diminishing returns which make investment in extended capabilities a justifiably economic business case, it is a question of what value a project programme places on having an extra few 'workable' days in an average installation project.

A 'high confidence' was expressed by industry in the outlook for this indicator, backing up the sentiment that 2020 targets look likely to be comfortably achieved.

35.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Sea conditions for most sensitive phases of cable installation limited to 1.6 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation limited to 1.7 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation limited to 1.8 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation limited to 1.8 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation comfortably exceeds 1.8 m Hs with the majority of tasks safely taking place beyond this limit.

On target	Sea conditions for most sensitive phases of cable installation limited to 1.5 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation limited to 1.6 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation limited to 1.7 m Hs with the majority of tasks safely taking place beyond this limit.	Sea conditions for most sensitive phases of cable installation limited to 1.8 m Hs with the majority of tasks safely taking place beyond this limit.	90% of projects will have an operational wave height limit of 1.8 m Hs for the most sensitive phases of cable installation work, with the majority of tasks safely taking place beyond this limit.
Behind target	Sea conditions for majority of phases of cable installation limited to 1.4 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.5 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.6 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.7 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.8 m Hs with significant number of tasks taking place at lower limits.
Missed target	Sea conditions for majority of phases of cable installation limited to 1.3 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.4 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.5 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.6 m Hs with significant number of tasks taking place at lower limits.	Sea conditions for majority of phases of cable installation limited to 1.7 m Hs with significant number of tasks taking place at lower limits.

35.3 Evidence

35.3.1 Questionnaires

Category	Questionnaire response
What is the operational wave height (in m Hs) that you would consider achievable for cable installation now? Discuss any options for increasing this.	
[Installation]	Cable installation in 3 m Hs is regularly undertaken by the Siem Aimery and her crew (see [PROJECT] & [PROJECT] wind farms). The cable's physical characteristics become the limiting factor for most installation weather limits due to the amount of catenary required vs flexing vs potential for 'shocking' the cable. Increasing cable installation limits beyond 3m Hs is possible - but it requires expensive vessel configuration for marginal gains.
[Developer]	HS 1.5 m is generally acceptable for non-motion compensated crew transfers at sea. Smaller scale CTV mounted motion compensated systems would allow for large volume / greater concurrency of crew transfers.
[Developer]	2.5 m for cable laying and transfers due to developments on walk-to-work systems.
Discuss how operational limits (in m Hs) vary for different phases of the cable installation process.	
[Installation]	Any time you are entering the 'splash zone' with equipment you will have reduced limits versus having something already deployed through the water column. Amongst other reasons this has to do with the potential for slamming effects on the device going into the water column. To an extent this can dealt with specialized Launch & Recovery systems for e.g. the ROV or trencher, or active compensation when deploying the cable quadrant for the second end.

[Developer]	The Crew Transfer limit has generally been the limiting factor for cable installation operations. However for the non-crew transfer aspects of cable installation activity, the following generally reflects the different phases. Lower Hs limits in shallow water, greater limits for non-crew transfer operations. Increasingly greater Hs limits for heave/motion compensated launch and recovery systems.
[Developer]	The most critical activities would be transfers and launch and recovery systems, when no new technology is used (limited to ~1.5 m).

35.3.2 Interview

Category	Interview response
None for this indicator	

35.3.3 Market intelligence

Evidence	Source
• Siem Offshore stated that the new cable layer Siem Aimery has a hull design that permits cable-handling operations in a significant wave height of up to 3.5 m.	http://www.owjonline.com/news/view,adverse-weather-is-no-obstacle-to-new-

	cablelayer_43770.htm
• The Siem Duo consisting of the Cable Lay Vessel (CLV) Siem Aimery and the Installation Support Vessel (ISV) Siem Moxie, demonstrated their advanced weather operability during the Nordsee One Offshore Wind farm project and particularly with gangway access being completed in up to significant wave heights of 3 m from the (ISV) Siem Moxie.	http://www.siemoffshorecontractors.com/en/news/siem-offshore-contractors-completes-inter-array-grid-cable-installation-works-of-the-nordsee-one-offshore-wind-farm

35.4 Additional comments

None for this indicator

35.5 Recommendations

None for this indicator

36 Optimised cable installation vessels and tooling

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Installation	Cables	Optimised cable installation vessels and tooling

36.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target	⇨	Medium confidence

Finding: On target

Marked as ‘on target’ in 2016 because there is clear evidence that the majority of cable installation projects are employing new or recently purpose build self-propelled cable installation vessels along with a continuously evolving suite of supporting installation tools.

Last year this indicator was also assessed as ‘on target’ noting the general trend away from older or converted vessels or barges to a highly specified fleet of new and relatively recently delivered offshore cable installation vessels.

Outlook:

A ‘medium confidence’ was expressed by industry in the outlook for the future of this indicator. This is perhaps cautious, as there appears to be a continuing steady improvement in the vessels and tooling used for cable installation and there does not appear to be any significant barrier to achieving the ‘on target’ milestone in 2020.

36.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Isolated use of non-purpose built vessels. Three quarters of installations undertaken by purpose built vessels with new cables installation tools.	Isolated use of non-purpose built vessels. Three quarters of installations undertaken by purpose built vessels with new cables installation tools.	Isolated use of non-purpose built vessels. Three quarters of installations undertaken by purpose built vessels with new cables installation tools.	Optimised purpose built cable installation vessels have 100% of the market	Purpose built cable installation vessels, using advanced tools, install over half of projects
On target	Purpose built cable installation vessels, using advanced tools, install over half of projects	Three quarters of installations undertaken by purpose built vessels with new cables installation tools.	Three quarters of installations undertaken by purpose built vessels with new cables installation tools.	Three quarters of installations undertaken by purpose built vessels with new cables installation tools.	Optimised purpose built cable installation vessels have 100% of the market
Behind target	Purpose built cable installation vessels, using advanced	Purpose built cable installation vessels, using advanced	Isolated use of non-purpose built vessels. Three quarters of	Isolated use of non-purpose built vessels. Three quarters of	Isolated use of non-purpose built vessels. Three quarters of

	tools, install over half of projects	tools, install over half of projects	installations undertaken by purpose built vessels with new cables installation tools.	installations undertaken by purpose built vessels with new cables installation tools.	installations undertaken by purpose built vessels with new cables installation tools.
Missed target	No new build vessels commissioned	No new build vessels commissioned	First use of purpose built cable installation vessels	First use of purpose built cable installation vessels	First use of purpose built cable installation vessels

36.3 Evidence

36.3.1 Questionnaires

Category	Questionnaire response
Considering the cable lay and burial process, discuss any new trenching, ploughing or recovery tools that have been introduced recently.	
[Installation]	This is publically available data, consider [COMPANY], [COMPANY], [COMPANY], [COMPANY], [COMPANY], [COMPANY], [COMPANY], [COMPANY], [COMPANY]
[Developer]	New tools have entered the market but they are similar in principle. Exception being the introduction of a tracked trencher/cutter with 4 independent tracks

[Developer]	SCAR plough, but it is limited in its application.
Discuss the capability of any new cable installation vessels which have been introduced recently. How do these compare to the existing available fleet?	
[Installation]	The Siem Aimery represents a step-change in array cable installation vessels. Designed to work in harsh environments (3 m Hs cable lay) and permanently mobilized for cable installation activities with subdeck cable carousels, a partially covered cable handling deck, permanent Trenching ROV, two Work class ROVs, 60 person high quality low noise accommodation, cable quadrant via A-frame and an experienced crew. In moving away from utilizing multi-role vessels for cable installation we are realizing significant mobilization cost reductions, and increased efficiencies in both the cable lay and trenching activities. The Siem Aimery works in partnership with the Siem Moxie which deploys personnel and pull-in equipment onto the Transition Pieces - eliminating the need for engineers to 'bump and jump' and increasing weather operability at the foundations.
[Developer]	There are now more purpose built cable lay vessels emerging that can meet the specific needs of the offshore renewables sector, i.e. anchoring, grounding, large capacity carousels etc.
[Developer]	New vessels have attempted to optimize by increasing the ability to conduct activities simultaneously.
Which cable installation vessels do you expect to use on your next or future projects?	
[Installation]	Siem Aimery
[Developer]	Ndurance, Stemat Spirit, Grand Canyon

[Developer]	Not known
Would you consider cable lay and burial an optimised and standardised process?	
[Installation]	Yes
[Developer]	No
[Developer]	Yes

36.3.2 Interview

Category	Interview response
None for this indicator	

36.3.3 Market intelligence

Evidence	Source
• In February 2016, the new advanced cable installation vessel, Maersk Connector, has arrived to North East England to start a long-term charter with the Darlington-based DeepOcean. The 138 m long vessel has the	http://www.offshorewind.biz/2016/02/26/de

ability to take the ground when fully loaded allowing DeepOcean to install cables from the beach, in shallow and deep waters. It will be used for the mobilisation of specialist cable handling equipment for projects in the offshore renewables and subsea interconnector sectors.	epocean-takes-over-maersk-connector/
• The cablelay vessel Siem Aimery, the latest addition to the Siem Offshore fleet, was named on 27 April 2016 at Remontowa Shipbuilding in Gdańsk, Poland. The vessel then underwent final mobilisation prior to commencing cable-loading activities for its first project assignment. Siem Aimery was designed for the installation and repair of medium and high voltage submarine cables. Siem Aimery started work with Siem Moxie, installing the inner-array grid and export cable systems for the Nordsee One offshore windfarm in the coming months. Thereafter, the vessel will continue with the winter installation campaign of the inner-array grid cable system of the Veja Mate offshore windfarm in the German Bight.	http://www.owjonline.com/news/view,adverse-weather-is-no-obstacle-to-new-cablelayer_43770.htm
• In June 2016, VBMS has been awarded a contract by EDF Energy Renewables to provide the subsea connection between the offshore turbines and the onshore grid for the Blyth offshore wind farm. VBMS will be using one or more of its cable-laying vessels and burial tools and has contracted Nexans as the supplier for the 66 kV cables. Work is scheduled to commence in 2017.	http://www.vbms.com/en/news/detail/vbms-first-to-install-66kv-cables-for-blyth-offshore-wind-farm+X139:AB139X139:AA139
• On September 18, 2016 DEME launched the world's most advanced subsea cable installation and trenching vessel 'Living Stone' at the LaNaval shipyard close to Bilbao, Spain. The cable installation vessel 'Living Stone' is engineered with the latest innovations in its category. The vessel is equipped with two turntables below deck, each having a 5,000 tons cable capacity. Together the turntables can carry and transport more than 200 km of cable that can be installed in a single trip. Ample deck space of 3,500 m^2 facilitates a revolutionary cable handling system with innovative and reliable cable handling tools for cable ends, connections and cable	http://www.deme-group.com/news/deme-launches-worlds-most-advanced-subsea-cable-

protection systems. Furthermore, the 'Living Stone' can be equipped with a third carrousel above deck with an additional load capacity of 2,000 tons and a 600 tons crane. A system developed in-house by Tideway enables the 'Living Stone' to install cables faster and more efficiently in longer lengths and with less offshore joints than any other cable installation vessel. The vessel will serve transport and installation projects as well as offshore power cable installations, interconnectors for the future European Supergrid amongst others.	installationtrenching-vessel-living-stone
• Siem Offshore Contractors announced that all 70 km of inter array grid cables on the Nordsee One Offshore Wind Farm in the German Bight of the North Sea have now been installed, terminated, trenched and tested three weeks ahead of schedule. All 59 cables were successfully installed using the "Siem Duo" consisting of the Cable Lay Vessel (CLV) Siem Aimery and the Installation Support Vessel (ISV) Siem Moxie. These were supported by a further in-house Multi-Purpose Vessel (MPV) Siddis Mariner, which provided subsea support for the installation of cable protection systems and concrete mattresses.	http://www.siemoffshorecontractors.com/en/news/siem-offshore-contractors-completes-inter-array-grid-cable-installation-works-of-the-nordsee-one-offshore-wind-farm
• DEME has announced the keel laying for its new multipurpose vessel Living Stone. It will be able to accommodate up to 100 people and will serve turbine as well as cable installation. Ship delivery is planned for 2017. It will be equipped with two large 5,000 tons cable/umbilical carrousels arranged below deck allowing for a free deck space of approx. 3,500 m² which accommodates the modular cable/umbilical handling systems, ROVs, the subsea trenching tool CBT 1100 and the fall-pipe system.	http://www.offshorewindindustry.com/news/new-multipurpose-vessel-way
Ecosse subsea have announced investment in new technology which has the potential to significantly increase the speed of cable burial activities.	http://www.4coffshore.com/windfarms/ecosse-invests-in-subsea-

	trencher-nid4777.html

36.4 Cable installation vessels

This table provides intelligence collected on the contractors and vessels employed for offshore cable installation in 2016.

Site name	Vessel (contractor)	Status	Notes
Burbo bank extension	Willem de Vlamingh (Jan De Nuul)	Existing vessel (2013)	
Dudgeon	Ndeavor (VBMS)	Existing vessel (2013)	
Galloper	Ndurance / Ndeavor(VBMS)	Existing vessel (2013)	
Race bank	Isaac Newton (Jan De Nuul)	New build (2015), new tools	
Rampion	Stemat spirit (VBMS)	Existing vessel (2010), new tools	Lay and simultaneous burial of cables. VBMS recently added a new plough to the spread

Walney extension	Maersk Connector (DeepOcean)	New build, new tools	Several advanced tools available

36.5 Additional comments

None for this indicator

36.6 Recommendations

None for this indicator

37 Turbine Condition based maintenance

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Operations and maintenance	Operations and maintenance	Turbine Condition based maintenance

37.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	On target	↓	Medium confidence

Finding: On target

Marked as ‘on target’ in 2016 because whilst there is some evidence of condition based maintenance in evidence from both WTG OEMs and developers/operators there does not appear to have been a significant change in this area in the past 12 months.

In 2015 this indicator was assessed as ‘ahead of target’ noting that the 20% threshold target was anticipated to have been met for projects in the EU reaching FID in that period.

All turbine OEMs understand and describe the power of increased volumes of data from operating assets, and the significant potential that integration of data systems and analytics can offer to the operations and maintenance phase. However, the amount of projects that can actually describe something approaching condition based maintenance strategies remains small, with conservatism, warranty implications and commercial considerations all described as potential barriers to the more widespread adoption of condition based techniques.

Outlook:

The adoption of condition based maintenance strategies also depends on learning through experience, and the development of deeper understanding of component and plant reliability. At present there are very few offshore wind projects which have reached the end of their design life, and as such it is perhaps understandable that the comprehensive understanding required to facilitate condition based maintenance is in a nascent phase.

In future it does look likely that in offshore wind as well as in other industries there will be an increasing use of data, sensing and a deeper understanding of condition driving maintenance activities, the technology in many instances exists already to enable this, with analytical techniques and contracts requiring development to enable the benefit of more targeted maintenance to be delivered.

A ‘medium confidence’ was expressed by industry in the outlook for this indicator, reflecting the fact that although potential for cost reduction exists, there is as yet no certainty around how it can be unlocked.

37.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	50% of turbines contracted have fully integrated control, condition monitoring and SCADA systems and are maintained using CBM.	70% turbines contracted have fully integrated control, condition monitoring and SCADA systems and are maintained using CBM.	All turbines contracted have fully integrated control, condition monitoring and SCADA systems and are maintained using CBM.	All turbines contracted have fully integrated control, condition monitoring and SCADA systems and are maintained using CBM.	All turbines contracted have fully integrated control, condition monitoring and SCADA systems and are maintained using CBM.

On target	20% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 20% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	50% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 50% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	70% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 70% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	All turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). All turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 100% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	All turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). All turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 100% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.
Behind target	10% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using	20% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using	30% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using	50% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using	70% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using

	strategies informed by the study of optimising the balance between maintenance, downtime and yield. 10% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	strategies informed by the study of optimising the balance between maintenance, downtime and yield. 20% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	strategies informed by the study of optimising the balance between maintenance, downtime and yield. 30% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	strategies informed by the study of optimising the balance between maintenance, downtime and yield. 50% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	strategies informed by the study of optimising the balance between maintenance, downtime and yield. 70% of contracted turbines have fully integrated control, condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.
Missed target	Improvements in the automatic integration and interpretation of all turbine operational data. This includes low frequency (1 Hz) data from the control system and the SCADA system, high frequency (500 Hz) condition monitoring data, turbine design data and turbine maintenance histories from technician records.	10% of turbines contracted have fully integrated control, condition monitoring and SCADA systems and are maintained using CBM.	20% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 20% of contracted turbines have fully integrated control,	30% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 30% of contracted turbines have fully integrated control,	50% of turbines are maintained using condition based maintenance (e.g. dynamically, not fixed service intervals). These turbines are maintained using strategies informed by the study of optimising the balance between maintenance, downtime and yield. 50% of contracted turbines have fully integrated control,

			condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.	condition monitoring and SCADA systems designed to enable CBM and cross department information sharing.

37.3 Evidence

37.3.1 Questionnaires

Category	Questionnaire response
Describe the extent to which your maintenance activities are informed by condition monitoring systems and analysis.	
[WTG OEM]	We have a sophisticated CMS system on all our offshore WTGs. It monitors vibration, humidity, temperature etc. at various points in the nacelle.
[WTG OEM]	Sophisticated control and monitoring via SCADA
[WTG OEM]	Confidentiality considerations

[Developer]	Condition based maintenance is generally only used where oils are concerned i.e. transformers and gearboxes. Analysis is carried out remotely but is generally not driving maintenance.
[Developer]	We have vibration monitoring on all our offshore WTGs and provisions to actively monitor the data to look for failure symptoms. We also take the SCADA signals and perform statistical analysis to determine outlying behaviours compared to the rest of the fleet.
Are you planning to move the focus of maintenance strategies towards fully condition based maintenance planning? What are the barriers and benefits associated with this type of approach?	
[WTG OEM]	No. The sensor reliability is a key barrier
[WTG OEM]	Already do
[WTG OEM]	Confidentiality considerations
[Developer]	This will be a gradual move – we don’t anticipate fully CBI implementation in near term. I don’t think the technology is at a point where it can be implemented fully yet.

To what extent are turbine control, condition monitoring and SCADA systems integrated? To what extent is data from these systems shared between teams, departments and companies?	
[WTG OEM]	They are fully integrated and the data is shared with our technical teams for trouble shooting purposed
[WTG OEM]	Different customers taking different approaches. Engineering led companies often want to do their own O&M so want access to all data
[WTG OEM]	Confidentiality considerations
[Developer]	Generally these systems are associated (routed through the SCADA) although the CMS does not influence the control system other than to initiate an alarm. Access to the systems needs to be granted and it would depend on the requirement of the team as to what level of access is granted. During warranty periods the OEM generally retains access to all data although control may be limited depending on the level of support provided.
[Developer]	CMS uses signals from SCADA (e.g. power) and CMS triggers SCADA alarms for major vibration breaches. The data is shared with site, local analysis and global analysis teams.
How has your use of condition monitoring systems changed recently if at all? Do you expect this to change significantly in the next 3 years?	

[WTG OEM]	No significant change
[WTG OEM]	Continual improvement process - More can be done remotely to cut down turbine visits. Better use of data expected.
[WTG OEM]	Specific innovation in CMS development. Continuous improvement thanks to operating fleet.
[Developer]	Use of CMS depends on the asset and the amount and type installed. Generally the use is increasing where more monitoring equipment is installed. Over the next 3 years it is not foreseen that there will be a step change in the use of CMS more of an iterative gradual increase.
[Developer]	Vibration CMS is new to us as a business as it has more utility offshore than onshore. I expect us to build our capability to use the technology considerably in the next 3 years

37.3.2 Interview

Category	Interview response
Describe the extent to which your maintenance activities are informed by condition monitoring systems and analysis.	

[O&M]	This has to be considered in the two worlds that dominate offshore wind – in warranty (OEM driven servicing) and out of warranty (Operator driven servicing). In terms of in warranty [O&M] are under the impression that planning and scheduling dominates as opposed to CBM. It is difficult to spot patterns in condition monitoring data therefore a proactive CBM approach is challenging. However, it is hard to judge how much CBM is being used due to the lack of open communication with the OEMs. Out of warranty operators appear to be more organised than OEMs. They have more invested interest in the long term profitability of a wind farm and want to see more predictability around O&M planning and costs. As a result, data is being used more regularly for maintenance planning and there are lots of good opportunities. Due to the increasing use of data, [O&M] have developed software products to assist with preventative maintenance approaches. A number of operators have had bad experiences with OEMs providing service due to poor planning and are not selecting to extend their service agreements beyond the warranty period.
[Developer]	Maintenance is more and more based on condition monitoring. Are doing quite a lot of work between O&M team at operational site and R&D team, and progress is happening that way.
[Blades]	There is always a trade-off, have to make the blade robust to last design life, but also need to make blades lighter, it is a very involved optimisation and trade off, which they need to work in very close coordination with turbine OEMs and blade customers. Have been doing a lot of innovation in how to design and improve structural performance and optimise the balance of strength, weight and customer performance requirements. There is capability to do remote condition monitoring of blade structure, depending upon which transducers are embedded into blade. The appetite for this type of innovation and data varies between customers, and not everyone wants to adopt this, although some customers do ask for it.

	Especially in the UK the wind density is more significant, and to some extent the appetite for blade structural health monitoring is related to the different geographies which customers will chose to deploy blades in. Factors influencing requirement for health monitoring include Air density, temperature ranges/extremes, and level of salinity in air. These factors all influence blade design and a requirement for monitoring.
Are you planning to move the focus of maintenance strategies towards fully condition based maintenance planning? What are the barriers and benefits associated with this type of approach?	
[WTG OEM]	It is perhaps suboptimal for moderately sized owner/operators to all go out and build a very sophisticated control room and data analytics function, lots of repetition and varying levels of expertise and experience. The number of turbines that different operators control varies significantly, and so the competence of different developers in condition monitoring will vary. [WTG OEM] have made an effort to bring not just service but also coordination of personnel and resources into the control room environment and feel that they are at least as smart as some of their most advanced customers in planning maintenance and use of data/CMS. There is a perception that having service performed by the OEM is a premium service. However overall lowest system cost would probably be based on [WTG OEM] maintaining all turbines under one roof and gaining cost efficiencies through sharing vessels, spares, personnel etc. although not everyone would agree.
[Developer]	Increased number of windfarms coming out of warranty as we believe we can reduce O&M costs & experience in operating for yield rather than remaining within the warranty.

	Improved planning on clusters More data around technical challenges, not just major components

37.3.3 Market intelligence

Evidence	Source
• On 04/05/16 ABB, the Swiss power and automation technology group, unveiled its new Remote Condition Monitoring service at this year's Hanover Fair. The service helps in predictive maintenance planning by utilising remote data and includes an expert analysis report on the drive's condition. It also provides proactive e-mail alerts regarding potential faults or limited availability with the aim to ensure that equipment is available, reliable and maintainable.	http://www.maritimejournal.com/news101/onboard-systems/monitoring-and-control/abbs-new-remote-condition-monitoring
• On 12/07/2016 Instrumentation designers cmc Instruments GmbH worked with local academia to engineer a real time sensor system, WearSens®. Now they have joined forces with offshore logistics experts Speedwind Offshore GmbH to bring the solution to windfarms. Condition-based maintenance from continuous, online monitoring by the WearSens® system from cmc Instruments provides detection of critical operating conditions, oil change on demand, damage prevention, increase turbine lifetime and real time information of oil condition and turbine stress. WearSens® is easy to install, has a small footprint and is inexpensive to retro-fit. The decentralised, web based monitoring system makes results available anywhere in the world. It can be employed as a stand-alone unit or as part of a more comprehensive condition monitoring system.	http://www.petro-online.com/news/fuel-for-thought/13/cmc_instruments_gmbh/condition_based_maintenance_cbm_-

	_optimized_cost_saving/39608/
• In October 2016, Offshore engineering solutions provider Aquaterra Energy and Proeon Systems, a provider of turnkey safety and control system services, have jointly developed a new integrated structural monitoring system for offshore wind projects. In addition to improving inspection and repair planning, the system is expected to reduce the need, risk and cost associated with inspection crews travelling to offshore sites. It will also provide accurate, informed, and real-time condition analysis data to operators to enhance maintenance, commissioning and decommissioning programs.	http://wind.energy-business-review.com/news/aquaterra-proeon-develop-monitoring-technology-reduce-offshore-wind-turbine-failures-131016-5030323

37.4 Additional comments

None for this indicator

37.5 Recommendations

None for this indicator

38 Access from vessel to turbine

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Operations and maintenance	Operations and maintenance	Access from vessel to turbine

38.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ for 2016 because whilst there was significant variance in evidence from engagement, an average for working wave height limits from across the industry and various vessel technologies of 1.7 m Hs does seem plausible. There was some evidence of more sophisticated planning and decision making around use of vessels, but also a clear acknowledgement that there is significant remaining potential in optimising the use of vessels on a project by project basis.

Last year this indicator was also assessed as ‘on target’ noting that whilst a limit of 1.5 m Hs was almost a de-facto standard across the industry that there was experience of significant variance between the ‘on paper’ operating limits and those which were used in practice, which almost always tended to be lower or more conservative. This sentiment was again expressed in evidence collected this year.

The working conditions suitable for transfer from a CTV are dependent on several factors; the vessel size and hull design itself, the experience of vessel skipper and crew, as well as any additional access or motion compensation technology.

Engagement suggests that whilst several innovations in access technology for CTVs have been developed, there has been a limited uptake, particularly of more complex systems. It appears that the additional cost of such systems do not yet present a compelling business case to invest the amount required in return for a relatively modest increase in potential working conditions.

There is also a significant trend in the more widespread adoption of offshore crew accommodation for next generation operations projects which is covered in more detail in a subsequent indicator.

Outlook:

It looks likely that projects already using standard first or second generation CTVs will continue to do so. Third generation CTVs, typically larger and with SWATH, surface effect or other innovative designs have been described as offering significant advantages in terms of comfort and working wave height conditions.

The 2020 target for this indicator of transfers at up to 2.5 m Hs could be achieved for new projects which will use either new CTVs and/or SOV type vessels with 'walk to work' systems, however it is far from certain that the existing portfolio of projects will adopt such technology and/or increase the working limits beyond something in the 1.5 – 2.0 m Hs range.

A 'high confidence' was expressed by industry in the future outlook for this indicator, albeit close the boundary between 'high confidence' and 'medium confidence' demonstrating that there was reasonable confidence that working vessel transfer weather limits could be expected to increase.

38.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Transfers from vessel to turbine take place with wave height limits of up to	Transfers from vessel to turbine take place with wave height limits of up to	Transfers from vessel to turbine take place with wave height limits of up to	Transfers from vessel to turbine take place with wave height limits of up to	Transfers from vessel to turbine take place with wave height limits of up to

	1.9 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are underway.	2.1 m Hs as standard practice. Vessel accessibility forecast is routinely used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are underway.	2.3 m Hs as standard practice. Vessel accessibility forecast is routinely used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility have delivered improvements	2.5 m Hs as standard practice. Vessel accessibility forecast is always used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility have delivered improvements.	2.5 m Hs as standard practice. Vessel accessibility forecast is always used in planning near future (e.g. day ahead) maintenance activities. Every project uses an optimised selection vessels and access systems to achieve near continuous accessibility.
On target	Transfers from vessel to turbine take place with wave height limits of up to 1.7 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are planned.	Transfers from vessel to turbine take place with wave height limits of up to 1.9 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are underway.	Transfers from vessel to turbine take place with wave height limits of up to 2.1 m Hs as standard practice. Vessel accessibility forecast is routinely used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are underway.	Transfers from vessel to turbine take place with wave height limits of up to 2.3 m Hs as standard practice. Vessel accessibility forecast is routinely used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility have delivered improvements	Transfers from vessel to turbine take place with wave height limits of up to 2.5 m Hs as standard practice. Vessel accessibility forecast is always used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility have delivered improvements.

Behind target	Transfers from vessel to turbine take place with wave height limits of up to 1.5 m Hs as standard practice. Vessel accessibility forecast is rarely used in planning near future (e.g. day ahead) maintenance activities. No studies into optimising use of different vessel types for maximum accessibility are evident.	Transfers from vessel to turbine take place with wave height limits of up to 1.7 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are planned.	Transfers from vessel to turbine take place with wave height limits of up to 1.9 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are underway.	Transfers from vessel to turbine take place with wave height limits of up to 2.1 m Hs as standard practice. Vessel accessibility forecast is routinely used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility are underway.	Transfers from vessel to turbine take place with wave height limits of up to 2.3 m Hs as standard practice. Vessel accessibility forecast is routinely used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum accessibility have delivered improvements
Missed target	Transfers from vessel to turbine take place with wave height limits of up to 1.4 m Hs as standard practice. Vessel accessibility forecast is not used in planning near future (e.g. day ahead) maintenance activities. No efforts to optimise use of different vessel types for maximum	Transfers from vessel to turbine take place with wave height limits of up to 1.4 m Hs as standard practice. Vessel accessibility forecast is not used in planning near future (e.g. day ahead) maintenance activities. No efforts to optimise use of different vessel types for maximum	Transfers from vessel to turbine take place with wave height limits of up to 1.5 m Hs as standard practice. Vessel accessibility forecast is rarely used in planning near future (e.g. day ahead) maintenance activities. No studies into optimising use of different vessel types for maximum	Transfers from vessel to turbine take place with wave height limits of up to 1.7 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum	Transfers from vessel to turbine take place with wave height limits of up to 1.9 m Hs as standard practice. Vessel accessibility forecast is starting to be used in planning near future (e.g. day ahead) maintenance activities. Studies into optimising use of different vessel types for maximum

	accessibility are evident.	accessibility are evident.	accessibility are evident.	accessibility are planned.	accessibility are underway.

38.3 Evidence

38.3.1 Questionnaires

Category	Questionnaire response
What significant wave height (m Hs) would you consider reasonable for technician transfer with a standard crew boat without access technology?	
[WTG OEM]	2
[WTG OEM]	1.5 m/s is the industry norm but always at discretion of vessel skipper
Designer / Survey	N/A
[WTG OEM]	CTV Catamaran: 1.5 m CTV SWATH: 2.0 m

[Installation]	UP TO 1.8 m Hs
[Developer]	With current vessels 1.75 – 2.0 m Hs
[Developer]	1.75 m using a SWATH or equivalent.
What significant wave height (m Hs) would you consider reasonable for a vessel using more advanced access technology? (E.g. motion compensation/walk to work).	
[WTG OEM]	3
[WTG OEM]	2.5 m/s
Designer / Survey	N/A
[WTG OEM]	CTV Catamaran: 2.0 m SWATH: 2.5 m SOV: 3.5 m

[Installation]	Siem Moxie regularly transfers personnel and equipment in 3 m Hs on O&M projects. The Siem Marlin and Siddis Mariner are active in 2- 2.5 m Hs.
[Developer]	2.5 m Hs
[Developer]	2.5 m HS (using a OSV DP2) but it depends on many factors
Discuss any projects which you are aware of which are seeking to improve this limit. How do you expect these limits to change in the next 3 years?	
[WTG OEM]	There are lots of R&D projects looking at putting advanced transfer systems on CTVs (e.g. Carbon Trust OWA). However, the issue is always the trade-off between proven technology, increased rental cost and increased access windows.
[WTG OEM]	Driven by vessel strategies, deployment of SOV type vessels increase turbine access significantly
Designer / Survey	N/A
[WTG OEM]	Confidentiality considerations

[Installation]	There are a number of projects beginning to utilize SOVs for their O&M requirements. By utilising Walk to Work access gangways they are able to enhance, significantly, the amount of working hours over winter. I expect 3 m Hs to become the de facto standard requirement for next generation wind farms.
[Developer]	All projects will be reviewed to improve the access limit through improvements in the design of the CTV's, monitoring of the vessel motion and transit data along with access systems
[Developer]	We are in the OWA access group so consider that a suitable avenue for driving such developments
How do you forecast and make decisions about accessibility of vessel to turbine crew transfer? (E.g. when to mobilise staff, when to postpone work, the capability of vessels and crew and the quality of weather forecasts available). Do you expect this to change over the next 3 - 5 years?	
[WTG OEM]	The local service teams for specific windfarms make these decisions. No significant changes expected
[WTG OEM]	Marine co-ordinators employed who are highly experienced. We have installed around 1000 turbines offshore so know how to manage
Designer / Survey	Hopefully [COMPANY] can make an improvement in forecasting
[WTG OEM]	Weather forecasts to foresee if a minimum weather window will be available to carry out O&M activities. Minimum weather window determined according to vessel characteristics and scope of work.

[Installation]	This is done using 7 day forecasts but respond on hour by hour basis to weather windows - as the Siem Moxie, Siem Marlin and Siddis Mariner is effectively in-field permanently, it is able to use small windows of opportunity which would not be possible when using a shore to turbine based solution.
[Developer]	Improvements in weather data analysis along with local site, motion, transit and accessibility data should enable better forecasting of accessibility of vessel to turbine crew transfer.
[Developer]	We take commercially available forecasts and use site/marine experience to inform decisions.

38.3.2 Interview

Category	Interview response
What significant wave height (M Hs) would you consider reasonable for technician transfer with a standard crew boat without access technology?	
[O&M]	The current industry defacto standard limit of 1.5 m Hs before you can sail is reducing number of days to access sites. [O&M] believe safety procedures have driven this limit down over the years. Project access decisions which are driven by daily wind speed readings on turbines and at port are very limiting for planning working weather windows; this needs to improve. [O&M] have considered using a portable met station on their jobs to combat this.

What significant wave height (m Hs) would you consider reasonable for a vessel using more advanced access technology? (E.g. motion compensation/walk to work).	
[Installation]	Access systems may at the moment look like a bit of a red herring. For example consider a standard CTV, and then consider one which has an access system. The access systems may cost almost as much as the vessel itself. To determine if the access system is good value, consider that a standard CTV may be capable of 1.75 – 2 m seas, and may be weathered off 7 – 8 days per month. CTV on its own may cost £1700 – £1900/day, but with access system could be another £1500/day on top of the rate, making a vessel with an access system an expensive proposition. With an access system you may be able to cope with say 2.1 m seas, but there will still be some weather, perhaps down to 4 days per month. Consider that for the extra spend on an access system you could probably justify charter of another standard CTV, it is likely that spending money this way will result in having more days per month of access in total, as every system will still stop for weather eventually. These economics of access systems may be an explanation why they have not seen widespread adoption.
Discuss any projects which you are aware of which are seeking to improve this limit. How do you expect these limits to change in the next 3 years?	
[Installation]	Same matter of supply and demand [as for other vessels] exists in CTVs, perhaps tending towards oversupply at present.
[Developer]	An amalgamation of small, incremental improvements e.g. crew vessel improvements

How do you forecast and make decisions about accessibility of vessel to turbine crew transfer. (E.g. when to mobilise staff, when to postpone work, the capability of vessels and crew and the quality of weather forecasts available). Do you expect this to change over the next 3 - 5 years?	
[Installation]	[Installation] use CTVs for personnel transfer and try to do crew exchanges in port rather than out at sea.

38.3.3 Market intelligence

Evidence	Source
• In December 2015, Offshore Transfer Devices presented their Tube Docking Device (TDD) transfer system which is backed, funded and supported by the Offshore Wind Accelerator (OWA). The TDD transfer system is a light, compact device used to effectively stabilize, pin and grip the transfer position to a structure offshore.	http://www.offshorewind.biz/2015/12/22/access-systems-tdd-tube-docking-device/
• In December 2015, an article in OFFSHOREWIND.BIZ highlighted the increasing interest for the use of Motion Compensating Gangways. The article mentions that the offshore wind sector has brought in an innovative piece of engineering, the motion compensating gangway. With one of these pieces of equipment installed on board an accommodation vessel becomes a walk to work vessel. One of the latest companies to develop and market such gangways is UPTIME International AS, formed by two companies with expert experience, one in each of the two components of the motion compensating gangway. For more than ten years ICD Industries has been making control systems in Norway for motion compensated equipment to be installed in advanced vessel systems. Also in Norway, Marine Aluminium are the market leaders in the manufacture of large gangways and helidecks. The	http://www.offshorewind.biz/2015/12/15/access-systems-uptime-moving-forward-the-latest-motion-compensating-gangways/

products of the four year old company fall into two categories, their small, 8 m and 12 m gangway for Crew Transfer Vessels (CTVs) and their large, 23.4 m and 26 m gangway. Between them they can solve the crew transfer problems from vessel to turbine, and back, for all the possible variants encountered in the offshore wind sector. Recently Offshore WIND spoke about the two gangways to Svein Ove Haugen, the UPTIME Sales & Marketing Director in Norway. The smaller version, typically installed on the bow of a CTV is capable of a 30° elevation, and also 30° lower if that should be required. The 2.5 tonne 12 m gangway enables safe and stable personnel transfers in seas up to a maximum of 2.5 m Hs providing a safe operational ability at a higher sea state than would be usually possible with the thrust powered fender grip of a normal CTV. The heave and pitch absorption available with the active motion compensation makes this gangway even capable of providing a link between two vessels at sea both subject to the similar sea conditions. UPTIME also presented a larger model with the name UPTIME 23.4 m Gangway which gives the advance if a failure or even a hint of a failure occurs the trained operator will have been warned in good time, alerted by different states of failure warnings. A large walk to work vessel should be able to function in sea states well above what is usually considered the upper limit. The 23.4 m gangway operates comfortably in wave heights of 3.5 m Hs on a supply vessel and has even been tested at 4 m Hs on purpose designed and built walk to work vessels.	
• On 15 January, Bibby Marine Services Limited, part of Bibby Line Group, signed a contract with the Damen Shipyards Group for delivery of its first Service Operations Vessel (SOV) with walk-to-work access. The vessel, Bibby WaveMaster 1, will undertake offshore wind project work in the North Sea. It is the first vessel purpose-built for the transfer and accommodation of offshore personnel and aims to maximise working time and staff retention. The design guarantees fast, safe and comfortable access to turbines, at lower cost, up to 80% of the time, including in worst case scenario Central North Sea conditions, resulting in a vessel capable of providing access up to 3.1 m Hs.	http://www.damen.com/en/news/2016/01/bibby_marine_services_orders_first_ever_damen_service_operations_vessel
• Windcat Workboats has won the Renewable Energy Health & Safety Award 2016 with its WindGrip system. WindGrip, patent pending, provides safer access to offshore wind turbines in harsh and unpredictable seas by	http://www.offshorewind.biz/2016/01/29

increasing the grip of the vessel's fender on the boat landing using constant tension winches. Windcat says that WindGrip reduces the risk of a vessel breaking away from a boat landing during a transfer as a result of above average waves, as the grip of the fender is not only realised using the vessel's propulsion at the stern of the vessel, but by adding additional force directly at the interface between the vessel's fender and the boat landing on the wind turbine. The runners-up prize went to Deutsche Windtechnik, a new entrant to the UK market, for their hazard-reporting app (NCCAPA). The app was developed as a way of creating the right safety culture within the company from the outset, and to engage employees with the relevant issues.	/windgrip-wins-renewable-energy-health-safety-award-2016/

38.4 Additional comments

None for this indicator

38.5 Recommendations

None for this indicator

39 Access from shore to site

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Operations and maintenance	Operations and maintenance	Access from shore to site

39.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ in 2016 because evidence suggests that the evolution of CTVs continues, with a trend evident for larger and more capable vessels and reducing reliance on small 1st generation CTVs.

Taking the length of CTV as an approximate indicator of the generation and hence capability, it has been found that CTVs used on projects which had first power in 2016 had an average length of 23.08 m with 54% of vessels being greater than 22 m in length. There has clearly been an ongoing increase in vessel capabilities (this number is up from 47% of vessels greater than 22 m in length found in CRMF 2015). Several 3rd generation CTV have found work on commercial projects.

In 2015 this indicator was also assessed as ‘on target’ noting the gradual increase in size and capability of vessels described above.

Outlook:

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, suggesting that there are not perceived to be significant barriers to ongoing improvements in the capabilities of CTVs.

39.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	70% using 2nd gen. 10% 1st gen, 20% 3rd gen. Significant evidence that blended or alternative strategies are being considered at design phase, for example including use of larger service vessels or helicopters to maximise revenue for far offshore sites.	60% using 2nd gen. 30% using 3rd gen. 10% using 1st gen. First contract placed indicating that a blended or alternative logistics strategy will be used on a UK project, for example including use of larger service vessels or helicopters to maximise revenue for far offshore sites.	100% 2nd or 3rd gen. Far offshore sites regularly operate with a diverse logistics strategy, and frequently include larger service vessels or helicopter access to optimise maintenance access.	100% 2nd or 3rd gen, with majority of 3rd gen. Logistics concepts applying alternative access technology (such as large service vessels or helicopters) are used to deliver cost reduction on appropriate (farther offshore) sites.	100% 2nd or 3rd gen, with majority of 3rd gen. Logistics concepts applying alternative access technology (such as large service vessels or helicopters) are used to deliver cost reduction on appropriate (farther offshore) sites.
On target	70% using 2nd gen. First operational use of 3rd gen. First evidence that blended or alternative strategies are being considered at design phase, for example	70% using 2nd gen. 10% 1st gen, 20% 3rd gen. Significant evidence that blended or alternative strategies are being considered at design phase, for example	60% using 2nd gen. 30% using 3rd gen. 10% using 1st gen. First contract placed indicating that a blended or alternative logistics strategy will be used on a UK project, for	100% 2nd or 3rd gen. Far offshore sites regularly operate with a diverse logistics strategy, and frequently include larger service vessels or helicopter	100% 2nd or 3rd gen, with majority of 3rd gen. Logistics concepts applying alternative access technology (such as large service vessels or helicopters) are used to deliver cost

	including use of larger service vessels or helicopters to maximise revenue for far offshore sites.	including use of larger service vessels or helicopters to maximise revenue for far offshore sites.	example including use of larger service vessels or helicopters to maximise revenue for far offshore sites.	access to optimise maintenance access.	reduction on all appropriate (particularly farther offshore) sites.
Behind target	60% using enhanced 2nd Gen, 40% using 1st gen. First 3rd gen vessels are ordered. No evidence of operators seeking to optimise vessel selection strategy.	70% using 2nd gen. First operational use of 3rd gen. First evidence that blended or alternative strategies are being considered at design phase, for example including use of larger service vessels or helicopters to maximise revenue for far offshore sites.	70% using 2nd gen. 10% 1st gen, 20% 3rd gen. Mixed logistics strategies have not progressed from design concept phase.	60% using 2nd gen. 30% using 3rd gen. 10% using 1st gen. Limited application of optimised access strategies even for far offshore sites,	100% 2nd or 3rd gen. Far offshore sites often operate with a diverse logistics strategy, which can include larger service vessels or helicopter access to optimise maintenance access, some applications of CTV only strategies still in use for far offshore sites.
Missed target	No new crew transfer vessels operational with few designs on order. No evidence of operators seeking to optimise vessel selection strategy.	Only small number of enhanced crew transfer vessels on order. No evidence of operators seeking to optimise vessel selection strategy.	Only small number of enhanced crew transfer vessels on order. No evidence of operators seeking to optimise vessel selection strategy.	60% using 2nd generation. No evidence of operators seeking to optimise vessel selection strategy.	70% using 2nd generation. No evidence of operators seeking to optimise vessel selection strategy.

39.3 Evidence

39.3.1 Questionnaires

Category	Questionnaire response
What types of crew transfer vessels do you use on your operational projects and do you plan to change these? Please include length of vessels if known. Use these definitions if convenient: - 1st generation CTV: less than 22m length, ~12 passengers - 2nd generation CTV: greater than 22m length, ~20 passengers - 3rd generation CTV: at least as large as 2nd gen but may also include novel structure or propulsion/air cushions/pontoons/swath	
[WTG OEM]	2nd generation vessels. We'll only change vessels if there's a cost benefit in doing so
[WTG OEM]	Client dependant but have used all vessels in the market. CTV for near shore projects, SOV increasingly deployed for installation and O&M phase activities.
[WTG OEM]	CTV LOA 24 m, 12 passengers CTV LOA 26 m, 12 passengers SWATH LOA 26 m, 12 passengers
[Developer]	Mainly 2nd generation CTV's with some 1st and 3rd Generation

Referring to the same definitions, what types of crew transfer vessels do you plan to use on your next or future projects? Please include length of vessels if known.	
[WTG OEM]	As above
[WTG OEM]	Customer and project dependant
[WTG OEM]	SWATH LOA 30 m, 24 passengers
[Developer]	2nd & 3rd Generation
[Developer]	Not yet known
How do you develop offshore logistics strategy(s)? Discuss whether you feel that the technology available (Basic CTV, advanced CTV/swath, helicopter, SOV, or other methods) allows you to have an arrangement that is optimum for your current and future sites.	
[WTG OEM]	Offshore strategy is based on a number of factors (distance to shore, nearest port, available infrastructure etc.). [WTG OEM] will use the best technology that is available at the time taking into account the additional cost

[WTG OEM]	Not one size fits all. Different clients adopting different techniques e.g. London array use of hotel vessels. Far shore sites bring different demands. SOV vessels proving very effective.
[WTG OEM]	Logistics strategy developed considering averaged sea status, distance to port, wind farm size... so that LCOE is minimum.
[Developer]	We use logistics modelling software to assess weather downtime of the options – most commonly OMCE.

39.3.2 Interview

Category	Interview response
What types of crew transfer vessels do you use on your operational projects and do you plan to change these? Please include length of vessels if known. Use these definitions if convenient: - 1st generation CTV: less than 22m length, ~12 passengers - 2nd generation CTV: greater than 22m length, ~20 passengers - 3rd generation CTV: at least as large as 2nd gen but may also include novel structure or propulsion/air cushions/pontoons/swath	
[O&M]	[O&M]s partner company for vessels are generally going for larger vessels that are more stable. These vessels ease the process of both operating drones from the vessel and also setting up working platforms (for blade inspections). Large vessels also have improved range and are more comfortable for vessel crews. Further offshore [O&M] believe you need larger vessels that can perform better in deeper water.
[O&M]	There is a format change of vessels being used every couple of years. Different vessels come onto market and attract premium rates. There exists a range of vessels available in the supply chain that can service wind farms that range in

	distance offshore. The number of vessels available currently outweighs the market demand so the margins have dropped for vessel suppliers. As a result there has been consolidation in the market for vessel suppliers, as a result we now have more vessels available today but with fewer suppliers. Different technologies are being developed but the developers are most focussed on price and value for money. In last two years we have seen different transfer technologies being developed and SOVs come onto the market. At the minute, particularly SOVs, they are trialling these out on near shore wind farms and whilst there is the potential to deploy these in 2.5 m HS with a 30 day turn around, there is still some uncertainty as to where the cost benefit arises for the use of these vessel types e.g. at what distance from shore does the business case stack up against the high CAPEX for a SOV.

39.3.3 Market intelligence

Evidence	Source
• Rhode Island Fast Ferry has announced that the first U.S. offshore wind farm service vessel has now hit the water. The 21 m (69 foot) high speed catamaran is being built by Blount Boats at Rhode Island in the nation's north east. The vessel's electronics are now being tested, and this will be followed by interior work. The vessel is based on a South Boats IOW's design.	http://www.maritime-executive.com/article/first-us-offshore-wind-crew-boat-hits-the-water
• In April 2016, Seacat Services, based in the Isle of Wight, has been awarded a multi-million pound contract to provide crew transfer vessels for DONG Energy's Race Bank offshore wind farm, located off the North Norfolk Coast. The new crew transfer vessels will be used during the construction of Race Bank, and the vessels have been built in the Isle of Wight. All of Seacat Services' crew members on-board the vessel will also be UK	http://www.dongenergy.co.uk/news/press-releases/articles/uk-firm-to-provide-crew-transfer-vessels-for-

employees. The Seacat Services crew transfer vessels are expected to be in operation at Race Bank until the end of 2018.	race-bank-offshore-wind-farm
• In June 2016, Njord Offshore's two latest 26 m offshore crew vessels (24 pax), equipped with Volvo Penta's IPS900 Quad drives, was announced that are ready for heavy-duty use in the North Sea. After a successful year operating four new 26m crew transfer vessels (CTVs) fitted with Volvo Penta's IPS900 Quad drives, Njord Offshore – which transports crew to and from offshore windfarms – has added another two new 24 pax vessels with the same propulsion system to its fleet. The UK company now has 15 CTVs of 21 m and 26 m in its fleet.	http://www.volvopenta.com/volvopenta/uk/en-gb/_layouts/CWP.Internet.VolvoCom/NewsItem.aspx?News.ItemId=151944&News.Language=en-gb
• In September 2016, OffshoreWind.Biz's crew transfer vessel update showed that almost 45%of the purpose built crew transfer vessels in the offshore wind industry were owned or operated by eleven British companies and one Anglo-Dutch company, with 74 of the vessels owned or operated by one of two companies, Turbine Transfers Ltd. and Windcat Workboats.	http://www.offshorewind.biz/2016/09/02/crew-transfer-vessel-update/
• In September 2016, CWind, a service provider to the offshore wind industry, has announced that Transmission Capital Services (TCS) has chartered one of CWind's crew transfer vessels on a five-year contract to support works at offshore substations in the United Kingdom. CWind is using one of its MPC19 resin infused composite catamarans to provide the crew transfer services. In February this year, CWind won a 20-year contract from TC Westernmost Rough OFTO, managed by TCS, to maintain the secondary mechanical and electrical systems of both the offshore and onshore substations at the Westernmost Rough project.	http://splash247.com/cwind-awarded-crew-transfer-vessel-contract/
• In September 2016, Spanish shipyard Gondan lay the keel of the service operation vessel (SOV) for the windfarm technicians on Dong Energy's Race Bank offshore windfarm. The 81.1 m long vessel has a beam of 17.0 m and is the first of the two SOVs Gondan will deliver to Norwegian shipowner Østensjø Rederi. Both ships are being built according to the UT 540 WP design by Rolls-Royce Marine. The SOV will be equipped with an	http://www.owjonline.com/news/view,spanish-yard-lays-keel-of-

Uptime 23.0 m heave compensated walk-to-work gangway and a crew transfer vessel landing system with a bunkering facility. In addition to the gangway, an 11.0 m daughter craft will allow the safe transfer of maintenance technicians to wind turbines. The environmentally friendly vessel will have Rolls-Royce Marine's SAVe Cube system, based on variable rpm operation of the generator sets onboard, to reduce emissions. The new build is a dynamic positioning class 2 (DP2) SOV. It will have 60 single cabins and accommodate up to 40 wind turbine technicians in addition to a marine crew of 20.	race-bank-sov_44644.htm

39.4 CTV greater than 22m project uses

Vessel	Length (m)	Estimated project uses in 2016
World Mistral	23.65	2.00
Seacat Resolute	24.00	2.00
Seacat Volunteer	24.00	3.00
Sea Fox	24.00	1.00
CarboClyde	24.00	1.00
TMS Bittern	24.00	1.00

SEA HURRICANE	24.65	2.00
SEA GALE	24.65	2.00
SEA BREEZE	24.76	2.00
Seacat Defender	25.00	2.00
Seacat Vigilant	25.10	1.00
MV Sea Comfort	25.30	2.00
SEA STORM	25.70	3.00
MCS Kaver	25.75	2.00
MCS Sirocco	25.75	2.00
MCS Levanto	25.75	1.00
Njord Alpha	25.75	1.00
Arista	25.75	1.00

MCS Blue Norther	25.75	3.00
MCS Coromell	25.75	1.00
MCS Pampero	25.75	1.00
Offshore Wielingen	25.75	1.00
Seazip 1	25.75	1.00
Sure Shamal	25.75	1.00
Windea Three	25.75	2.00
Church Bay	26.00	1.00
Njord Thor	26.00	1.00
Njord Magni	26.00	1.00
Mill Bay	26.00	1.00
Njord Odin	26.00	1.00

Sure Dynamic	26.00	1.00
Njord Balder	26.20	1.00
MV Detecter	26.20	1.00
Njord Forseti	26.20	2.00
Umoe Ventus	27.00	1.00
MV Developer	27.20	2.00
MV Dispatcher	27.20	1.00
Ocean Wind 8	27.40	2.00
M/V Presto	27.50	1.00
Rhosneigr Bay	28.00	2.00
Cymyran Bay	28.10	1.00
Kem 1	28.17	1.00

Liz V	31.30	1.00
Estimated percentage of vessel uses over 22m length in 2016	**54.31%**	

39.5 Additional comments

None for this indicator

39.6 Recommendations

None for this indicator

40 Inventory management

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Operations and maintenance	Operations and maintenance	Inventory management

40.1 Summary Analysis

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

Finding: Behind target

Marked as ‘behind target’ in 2016 because whilst there was evidence from engagement that sophisticated and in many cased offshore wind specific inventory management systems were in place and used on projects there was almost universal agreement that this area is something which could be further improved and that there will be ongoing improvements to inventory management in the coming years.

Last year this indicator was assessed as ‘on target’ noting that whilst there was credible evidence of sophisticated and data driven approaches to inventory management there was a lack of detailed evidence sufficient to give confidence that scope for improvement did not remain.

A particular dynamic which has been highlighted in evidence from CRMF 2014, 2015 and 2016 is the level of collaboration or sharing of inventory information within a project. Engagement suggested that the transaction attitude of WTG OEMs towards a period of at least 5 years joint operations and maintenance with a developer/operator was probably not optimal from an inventory management point of view.

For example the owner of an asset commonly does not have visibility of where specific components are warehoused, when and why certain components on a WTG may have been replaced by the OEM, or other information for example about a recall of a batch of certain components.

Outlook:

Technology such as barcodes, RFID, and inventory management software exists sufficient to enable a highly sophisticated approach to inventory management and dynamic spares tracking and organisation. However the commercial and contractual structures necessary to enable projects to maximise benefit of a data driven approach generally do not. Whether there will be a fundamental change in the level of information sharing on inventory, particularly during the operations and maintenance phase is not certain.

A ‘medium confidence’ was expressed by industry in the outlook for this indicator. Potential for cost reduction remains, but the chances of all potential reductions being realised is uncertain.

40.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	80% of projects use techniques, some evidence of improved information sharing.	80% of projects use techniques, some evidence of improved information sharing.	90% of projects use techniques, strong indication that information sharing is well structured and happens at all project phases.	100% of projects use techniques. Fully integrated inventory information between all project participants at all project phases.	100% of projects use techniques. Fully integrated inventory information between all project participants at all project phases.
On target	70% of projects use techniques, limited evidence of	80% of projects use techniques, some evidence of	80% of projects use techniques, some evidence of	80% of projects use techniques, strong indication that	90% of projects use techniques. Fully integrated inventory

	improved information sharing.	improved information sharing.	improved information sharing.	information sharing is well structured and happens at all project phases.	information between all project participants at all project phases.
Behind target	60% of projects use techniques, limited evidence of improved information sharing.	60% of projects use techniques, limited evidence of improved information sharing.	70% of projects use techniques, some evidence of improved information sharing.	70% of projects use techniques, some evidence of improved information sharing.	80% of projects use techniques, strong indication that information sharing is well structured and happens at all project phases.
Missed target	50% of projects use techniques, no evidence of improved information sharing.	50% of projects use techniques, no evidence of improved information sharing.	60% of projects use techniques, no evidence of improved information sharing.	60% of projects use techniques, no evidence of improved information sharing.	60% of projects use techniques, no evidence of improved information sharing.

40.3 Evidence

40.3.1 Questionnaires

Category	Questionnaire response
What is your approach to inventory management? (e.g. have you put in place any systems that keep records of part numbers and variants including serial numbers of key components, build a history of spares usage, track the timescales required for replacements, track the cost of the component, detail the maintenance requirements for components that are held in storage and track the cost of transporting components).	

[WTG OEM]	Yes. We use RDSPP
[WTG OEM]	Yes, RFID, bar code systems in place.
[WTG OEM]	Related systems are implemented in our inventory management.
[Developer]	This is an ongoing and developing project.
[Developer]	We are implementing SAP based inventory management.
Do you have plans to evolve or improve inventory management in the next 3 years?	
[WTG OEM]	Yes
[WTG OEM]	Yes
[WTG OEM]	Yes

[Developer]	Yes
[Developer]	Yes
Describe the level of information sharing relating to inventory. For example do you feel that there is an optimal understanding between operators and OEMs, both during and out of warranty? Are you aware of spares inventory for all areas of your projects?	
[WTG OEM]	Yes. We have a standard spares list for all our turbines and spares can be ordered from us even after the warranty period.
[WTG OEM]	Continually improving
[WTG OEM]	There is good understanding at both stages
[Developer]	The exchange of information sharing between OEM & operators both in and out of warranty is an area for improvement and is also a commercial issue. It would be fair to say that the spares inventory for all areas of the site is not as clear as it should be.
Do you expect the level of collaboration on inventory management to change in the next 3 years?	

[WTG OEM]	No
[WTG OEM]	Yes
[WTG OEM]	No
[Developer]	Yes
[Developer]	No

40.3.2 Interview

Category	Interview response
Describe the level of information sharing relating to inventory. For example do you feel that there is an optimal understanding between operators and OEMs, both during and out of warranty? Are you aware of spares inventory for all areas of your projects?	
[O&M]	There is a growing trend towards Independent Service Providers providing materials for O&M, such as blade repair materials, as opposed to the client (Operator or OEM).

	[O&M] believe OEMs regard their relationship with the Operator as a transaction rather than a collaboration and for this reason cross inventory management of materials and spares is unlikely at present.
[O&M]	[O&M] are not currently exposed to the sharing of turbine spares and doing any warehousing. However, as the market matures this is likely to change

40.3.3 Market intelligence

Evidence	Source
None for this indicator	

40.4 Additional comments

None for this indicator

40.5 Recommendations

None for this indicator

41 Offshore crew accommodation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Operations and maintenance	Operations and maintenance	Offshore crew accommodation

41.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016 because there have been several announcements of projects designing their logistics concept around offshore crew accommodation, predominantly on the basis of using SOVs to keep a team of maintenance technicians and warehouse of spares offshore in the wind farm at all times. Offering the advantage of avoiding significant transit times compared to using CTVs and enabling transfer in greater sea states than achievable by conventional CTV.

Last year this indicator was also assessed as ‘on target’ with general sentiment of cautious optimism that offshore crew accommodation was being more actively considered and that new vessels were being ordered.

There have now been several announcements of projects across a range of developers, turbine OEMs and geographies that are either already using or expecting to deploy floating offshore crew accommodation. A single fixed offshore accommodation platform has been

delivered in the EU but appears to have been challenging. Supply chain concepts for fixed offshore accommodation platforms exist but remain on the drawing board.

Outlook:

The outlook for this indicator is positive, and it would be reasonable to assume that the 2020 vision will be achieved for any new projects added in the UK in the remaining years of this decade. There will inevitably be a steep learning curve in the wider adoption of SOV type maintenance logistics concepts, with considerable technical and commercial uncertainties remaining about this type of concept; they are still relatively unproven. However, there are several vessels which have long term commitments in the sector and wider use is expected in future.

Finally, a trend which has not yet been seen but which could offer further potential cost reduction may include the sharing of vessels or the rotation of an SOV by a WTG OEM around a fleet, for example where a particular campaign of maintenance is required.

A ‘medium confidence’ was expressed by industry in the outlook for this indicator, however it was very close to achieving a ‘high confidence’ rating, reflecting the fact that most in the industry see initial use of offshore crew accommodation as a trend that is anticipated to continue.

41.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Partial use of purpose-built mother ships that can remain permanently stationed at far from shore sites and undertake larger	Mother ships for 50% of far-offshore projects	Mother ships for 90% of far-offshore projects	Universal take up for far offshore sites	Universal take up for far offshore sites

	component replacement				
On target	Use of floatels without high-capability access methods. Designs emerging for high capability access method	Partial use of purpose-built mother ships that can remain permanently stationed at far from shore sites and undertake larger component replacement	Mother ships for 50% of far-offshore projects	Mother ships for 90% of far-offshore projects	Universal take up for far offshore sites
Behind target	Use of floatels without high-capability access methods	Use of floatels without high-capability access methods	Partial use of purpose-built mother ships that can remain permanently stationed at far from shore sites and undertake larger component replacement	Mother ships for 40% of far-offshore projects	Mother ships for 70% of far-offshore projects
Missed target	First use of floatels	Floatels unsuccessfully deployed.	No designs for purpose built mother ships emerge.	First use of purpose-built mother ships that can remain permanently stationed at far from shore sites and undertake larger component replacement	Partial use of purpose-built mother ships that can remain permanently stationed at far from shore sites and undertake larger component replacement

41.3 Evidence

41.3.1 Questionnaires

Category	Questionnaire response
Describe your approach to floating or fixed offshore accommodation during the operational phase of your projects.	
[WTG OEM]	We will use it if the location of the wind farm necessitates this
[WTG OEM]	Used on a number of projects e.g. [PROJECT]
[WTG OEM]	To be evaluated for distance, wind farm size, synergies with other wind farms, facilities provided by the wind farm owner...
[Developer]	Fixed offshore accommodation is not planned for with current projects, it may be considered for future developments further offshore. Floating accommodation is currently one of the options under consideration for one site.
[Developer]	None currently
Are you aware of any further developments in offshore accommodation likely to be available for the operations phase in future? For example service vessels with smaller daughter craft launched and recovered from a large vessel.	

[WTG OEM]	Yes
[WTG OEM]	No
[WTG OEM]	Increased use of SOV vessels expected.
[WTG OEM]	Yes, we are aware.
[Developer]	There are a number of developments within the Service vessel fleet typically using a small mono-hull daughter-craft. This type of daughter-craft will not have the accessibility of the current 2nd generation CTV's so will have limited use.
[Developer]	Through our involvement in OWA access group we are aware.

41.3.2 Interview

Category	Interview response
Describe your approach to floating or fixed offshore accommodation during the operational phase of your projects.	

[WTG OEM]	Developer has to trade off cost of availability against cost of having an SOV. There is an aggregation and effect of scale, would logically imagine that economies of scale should help to reduce costs and that bigger projects may justify/necessitate the decision to involve SOV in logistics model/planning. [WTG OEM] would of course like all customers to take a long term service, perception is that this service is premium in quality and price but they do challenge this. Have used mothership approach on London array, which was very successful.
[O&M]	[O&M] expect this to happen in the near future. It makes cost sense for construction but it is still not clear if it makes cost sense for O&M. This will depend on how O&M issues such as blade erosion are prioritised and handled in the future. The difficult and costs sensitive practicalities of accessing offshore projects makes good sense for O&M offshore accommodation.
[WTG OEM]	At the moment it seems like the industry has yet to come up with cost effective solution for dealing with very far from shore projects. People may not be so focussed on O&M because a change in O&M cost looks like a lower potential to reduce LCOE, but will increasingly see that there will have to be a look at all potential contributions from all areas, including O&M.
Are you aware of any further developments in offshore accommodation likely to be available for the operations phase in future? For example service vessels with smaller daughter craft launched and recovered from a large vessel.	
[WTG OEM]	Something that they are really working hard at is the process of shortening installation and commissioning. Completing this stage of work in 24 hours makes a big difference on how you operate construction offshore, and the amount of people who need to be stationed offshore for a long time.

	Have got some experience in using commissioning [PROJECT] as a trial period for new built SOV, this really was fantastic experience. It is an ideal vessel to support installation/commissioning. Dynamics of installation is changing by driving processes from months – weeks – days – hours. Marine coordination could start being done offshore. Simulation exercise, gets difficult to deal with all eventualities.
[Installation]	Do see more use of access systems on conventional OSV's from O&G markets, but could be that these type of vessels are being purchased more as a result of the low rates being commanded because of cross over with the currently depressed oil and gas market. New wind offshore service/supply vessels SOV are an interesting development, they have quite a high day rates, but are not moving around the field dropping people off as quickly or as agile as a CTV would be. It will be interesting to see how the concept is used and develops.
[O&M]	[O&M] have been working on projects using SOVs and the price points are very competitive. On some of the contracts (10 year with 5 year break point) they have been hearing about, [O&M] are unsure if a vessel developer would pay off the CAPEX of an SOV – the margins are very tight. SOV contracts are currently going for around 20k a day. Companies are just trialling SOVs right now to determine when the price point is right to use them and on what types of assets.
[O&M]	Currently all UK round 2 sites are trialling some form of offshore accommodation. The choice to use them depends on the price, weather conditions, distance from shore and flexibility of the vessels. SOVs need to go into DP mode before they can deploy there walk to work systems, which creates logistical challenges when accessing different turbine locations in the array. In comparison, CTVs are much more agile and can get technicians on different turbines in potentially less time. SOVs seem a good business case for O&M but not for construction where things need to be done much quicker and they have

	seen greater use of things like floatels with CTV access. Therefore, more trialling and experience with SOVs is required to find the best use-cases for them and we may continue to see a mixed environment between vessel type uses.

41.3.3 Market intelligence

Evidence	Source
• In December 2015, Esvagt confirmed it had also placed a contract to build a service operation vessel based on a Havyard design having secured a contract for the vessel from MHI Vestas Offshore Wind. The vessel, which is due to enter service in the second half of 2017, it will be 58.5 m in length with a beam of 16.6 m. It will have accommodation for 22 windfarm technicians in single cabins and be equipped with Esvagt's safe transfer boats to transfer technicians, tools and spare parts to turbines.	http://www.osjonline.com/news/view,esvagt-returns-to-havyard-and-cemre-for-another-new-design_44848.htm
• In October 2016, a press release stated that Voith is developing new design concepts for service operation vessels (SOV). Roman Grebe, chief executive of broker F3 Offshore, speaking in conjunction with Voith Marine Turbo at the SMM event in Hamburg, outlined some of the specific challenges posed by the demands on SOVs. In particular, SOVs have to provide substantial and high quality accommodation for technicians who work off the SOVs on wind turbines but are not seafarers. "SOVs require a high level of passenger facilities and comfort for workers. The current benchmark is to have about 40 technicians onboard, plus about 20 crew members. But some operators are looking at bigger SOVs. There are specific training requirements for crews of SOVs and for the technicians servicing offshore turbines," he said. Voith is working with several designers and shipbuilders to develop an SOV featuring an innovative Voith propulsion system, which the company believes will enhance performance, comfort, and fuel efficiency.	http://www.owjonline.com/news/view,voith-developing-new-design-concepts-for-sovs_44935.htm

• Vattenfall is set to install the long-delayed accommodation platform for its 288 MW DanTysk and 288 MW Sandbank offshore wind farms in the German North Sea. Seaway Heavy Lifting vessel Stanislav Yudin is being mobilised in Eemshaven, Netherlands, to install both the 1300 tonne jacket and 2500 tonne topside at the construction site some 70 km off the island of Sylt. The 44 m tall jacket will be installed at water depths of some 25 m. Vattenall expects the platform to host up to 50 O&M staff members and become fully operational in early July.	http://renews.biz/102796/dantysk-hotel-platform-setting-sail/
• The newbuild Spanish shipyard Gondan SOV designed for the Dong Energy's Race Bank offshore windfarm and will have 60 single cabins and accommodate up to 40 wind turbine technicians in addition to a marine crew of 20. The vessel will operate from an operations base in Grimsby on the east coast of the UK.	http://www.owjonline.com/news/view,spanish-yard-lays-keel-of-race-bank-sov_44644.htm
• Bibby wave master one	http://www.osjonline.com/news/view,norwegian-owner-diversifies-into-offshore-wind-with-rollroyce-design_44756.htm

41.4 Purpose built offshore wind offshore crew accommodation

Name	Type	Year	Notes
Horns Rev 2	Fixed accommodation platform	2009	Seasonal use
DanTysk	Fixed accommodation platform	2016	50 personnel
ESVAGT Faraday	SOV	2015	
ESVAGT Froude	SOV	2015	
WINDEA LA COUR	SOV	2016	
ESVAGT Njord	SOV	2016	Contracted to work on Dudgeon
TBN (ESVAGT for MHI Vestas)	SOV	2017	Scheduled to work on Nobelwind 1
TBN (WINDEA for Siemens)	SOV	2017	Scheduled to work on Vattenfall projects

EDDA TBN (Østensjø Rederi for Dong)	SOV	2017	Expected to work on Race Bank
Bibby Wavemaster 1	SOV	2017	
EDDA TBN (Østensjø Rederi for Dong)	SOV	2018	Expected to work on Hornsea

41.5 Additional comments

None for this indicator

41.6 Recommendations

None for this indicator

42 Transmission asset O&M

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Operations and maintenance	Operations and maintenance	Transmission asset O&M

42.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016. It has been challenging to collect evidence through engagement with the OFTO community, but some context and insight was gained from electrical supply chain and Developers. There was mixed evidence around the application of condition monitoring of transmission assets, with some suggestion that it is commonly specified at the design phase but with contrasting evidence suggesting that developers will not usually strive to include state of the art monitoring systems as they are under pressure from the OFTO disposal transaction to avoid specifications other than those which can be justified as absolutely necessary.

Last year this indicator was assessed as ‘behind target’, noting that whilst OFTOs were known to be considering cost reduction there was limited evidence of any improvements being made.

A trend has been described where a Developer/operator will actually provide maintenance services under contract to the OFTO company and will coordinate maintenance activities in the way they would for the other parts of the windfarm. This is perhaps a natural trend, as the

developer/operator is highly motivated to ensure adequate maintenance is carried out, as they depend on the asset to generate their revenue. This method of organising O&M activities demonstrates that OFTOs are financial companies, rather than having a technical interest in the asset, however, there have also been announcements of awards of maintenance contracts to third parties.

Conference presentations (for example from cable repair contractors) have described concepts of vessel sharing and various ways that could enable more cost effective reactive maintenance on OFTO assets (particularly export cables) by for example cooperating to have a repair vessel on standby at all times. This system is reflective on how other operators of subsea cable assets (telecoms) have dealt with a similar challenge. The amount of serious interest or chances of uptake of this approach by OFTOs is uncertain and could be assumed to be low.

Outlook:

It is clear that significant remaining cost reduction potential remains in more use of data, analytics and condition monitoring, as well as the potential for vessel sharing. A greater focus on the operation and maintenance of an OFTO asset at the design stage would likely offer the potential to reduce through life costs, but is not incentivised by the current scheme and looks unlikely to change.

A ‘medium confidence’ was expressed by industry in the outlook for this indicator. This reflects the sentiment that whilst there may be gradual improvements in the coming years, achievement of maximum cost reduction is not guaranteed.

42.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	Further improvements are implemented on projects, particularly in condition	OFTOs able to demonstrate cost savings. Vessels and spares starting to be shared.	Enhanced sharing of vessels and spares. Condition monitoring being used on over 30% of OFTO assets.	OFTOs utilise condition monitoring on majority of assets, with some sharing of vessels and spares, leading	Demonstrated cost savings of 10% of OFTO O&M cost on average across all projects.

	monitoring. Vessels starting to be shared			to cost savings of 10%	
On target	First improvements implemented leading to cost reductions. Plans for sharing of vessels discussed	Further improvements are implemented on projects, particularly in condition monitoring. Vessels starting to be shared	OFTOs able to demonstrate cost savings. Vessels and spares starting to be shared.	Enhanced sharing of vessels and spares. Condition monitoring being used on over 30% of OFTO assets.	OFTOs utilise condition monitoring on majority of assets, with some sharing of vessels and spares, leading to cost savings of 10%
Behind target	First incremental improvements starting to be implemented, including enhanced condition monitoring of assets.	First improvements implemented leading to cost reductions. Plans for sharing of vessels discussed	Further improvements are implemented on projects, particularly in condition monitoring. Vessels starting to be shared	OFTOs able to demonstrate cost savings. Vessels and spares starting to be shared.	Enhanced sharing of vessels and spares. Condition monitoring being used on over 30% of OFTO assets.
Missed target	No cost reducing options identified	No investigation by OFTOs into savings	No improvements implemented	First improvements implemented	Minimal cost saving identified

42.3 Evidence

42.3.1 Questionnaires

Category	Questionnaire response

Discuss any concepts you have witnessed or are planning to implement for reducing the O&M cost for the OFTOs. e.g. condition monitoring technologies or vessel sharing	
[Developer]	Many concepts for reducing the O&M costs of the OFTO centre on suitability & reliability of equipment and assets. Adding additional/advanced technology is generally avoided due to the difficulty in obtaining the acceptance from OFGEM for the additional costs to be included in the price for the asset sale. Vessel sharing has been done however there needs to be acceptance of true cost sharing between the parties.
In your experience has the margin obtained by OFTOs increased or decreased for recent projects? Do you expect this to change in the next few years? If so please discuss why.	
[Developer]	We, as the developer, don't have the visibility of the margin obtained by OFTOs but our guess is that it has decreased due to an increased competition among OFTOs and the resultant decrease of the required annual OFTO revenue. However we would welcome further decrease in the margin obtained by OFTOs in the future.
[Developer]	Unknown.

42.3.2 Interview

Category	Questionnaire response
[Electrical]	Condition monitoring; all switchgear is monitored as a matter of course, alarms etc. are in place and standard practice. Could also add monitoring to transformer to predict likely future failures. Nobody ever specifies that as a requirement of the transformer, current solution is periodic manual checking, spending OPEX to save CAPEX, there are ways that more

	monitoring could deliver a more optimum solution. Could be that a project will specify this in near future, but would be a first (probably) in the UK. Condition monitoring of the cable is fairly standard, temp monitoring by fibre optics, this is absolutely standard and all substations will have accommodate the equipment. OFTO's and developers could probably add more sophisticated monitoring to offshore assets, but people have not necessarily seen the need or been incentivised to go to next generation. Data and analytics could be a growing trend and a lot could be done with data, expect that this could be a growth area, including for turbines in future.
[Electrical]	OFTOS tend to be financial businesses rather than engineering businesses. Wind farm operator in one example is taking on responsibilities in maintenance for the OFTO, as they are the ones who would be impacted by the outage, so they would rather do the maintenance themselves. There is a trend in assets being maintained and/or having maintenance coordinated by developers/operators and performed on behalf of the OFTO with the OFTO as the client but the developer wanting to be certain that they will be able to make it work, an interesting trend.

[O&M]	[O&M] have secured a 20 year deal and are working on 3 OFTO projects out of {LOCATION] (as it stands) where they have operational base (quay side, vessels and office). At this base they have assets to deploy on more than one project, which is useful for the OFTO. Moving forward, there are 3 main OFTO companies who have secured most of the OFTO jobs to date with more being shortlisted. Developers are looking at different pricing models with OFTOs. These are least cost tenders at the minute. Different OFTOs are trying out different financing models. The finance companies make everything conservative. For example in the German sector, finance companies are looking to mitigate risk at a level they are comfortable with, but it is not always the most cost effective solution (this is still an immature industry).
[O&M]	[O&M] have been working on an agreement for a cooperative strategy to have centralised O&M assets for maintaining OFTO infrastructure. It would make sense for the industry to come together and collaborate in this area to minimise OFTO O&M costs. The challenge is that different developers will take time to come round to this approach as they like to have control of their own costs. This is still 'blue sky' thinking and not likely to happen pre 2020.

42.3.3 Market intelligence

Evidence	Source
None for this indicator	

42.4 Additional comments

None for this indicator

42.5 Recommendations

None for this indicator

43 Increased design life

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Increased design life	Increased design life	Increased design life

43.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there is strong evidence that the 2020 target for this indicator of projects using a 25 year design life has already been achieved and is being used on the vast majority of all projects currently in design/construction.

Last year this indicator was also assessed as ‘ahead of target’ noting that 25 year design life was almost universally adopted already.

The tax and regulatory regime imposes important dynamics on choice of appropriate design life by developers.

Outlook:

It looks unlikely that design life of less than 25 years will be specified on any new projects now. Whether the standard in design life will extend significantly beyond this remains to be seen, and it is possible that significant movement will not occur until more offshore projects have reached their specified design life.

There is growing interest in the topic of life extension, which whilst not tracked specifically by this indicator does have the potential to contribute to LCOE reduction. Data and understanding from full scale testing, component reliability study and structural health monitoring are all expected to drive an increasing focus on targeted life extension. The relationship between ongoing maintenance costs and the market price of electricity will be determining the actual operating life of projects once they have reached a mature stage and subsidy support ends.

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, reflecting the fact that design life is already achieving the 2020 target on almost all projects already.

43.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	More projects contract using 25 year design life	More projects contract using 25 year design life	Over 50% of projects contract using longer design life	Over 75% of projects designed for 25 years	All projects designed for 25 years
On target	First projects designed for 25 years, with range of turbines for this lifetime.	First project contracts for 25 years. Range of turbines on market with longer design life	More projects contract using 25 year design life	Over 50% of projects contract using longer design life	Over 75% of projects designed for 25 years
Behind target	Wind farms designed and financed on basis of 20 years. Turbine OEMs start to offer longer design life	First projects designed for 25 years, with range of turbines for this lifetime.	First project contracts for 25 years. Range of turbines on market with longer design life	More projects contract using 25 year design life	Over 50 - 75%of projects contract using longer design life

	products on the market				
Missed target	Wind farms designed and financed on basis of 20 years. Wind turbines start to be offered for 25 years	Wind farms designed and financed on basis of 20 years. Turbine OEMs start to offer longer design life products on the market	First projects designed for 25 years, with range of turbines for this lifetime.	First project contracts using 25 year design life	50% of projects designed for 25 years

43.3 Evidence

43.3.1 Questionnaires

Category	Questionnaire response
Describe your approach to determining design life at project initiation/FEED stage.	
[WTG OEM]	This is based on the approach of the certifying authority
[Insurance]	Track claims experience of the asset
[Finance]	Our role is to provide debt finance for offshore wind projects, hence question is more relevant for equity / project developer stakeholders. Our view on appropriate design life assumption is informed by the opinion of lenders technical advisor.

[Foundation]	Recommended practices such as DNG-GL standards.
Designer / Survey	N/A
[WTG OEM]	IEC 61400-3 Edition 1º and DNV- OS J 1O1
[Developer]	Design life has been set at up to 25 years in our projects to date.
[Developer]	Assessed as part of Feed generally 25 years for an offshore wind farm
What is the design life you are planning for on your current or near future projects? Do you expect this to change in the next 3 - 5 years?	
[WTG OEM]	25 years. No change
[Insurance]	n/a for Insurance company
[WTG OEM]	Projects now based on 25 year design life
[Finance]	N/A
[Foundation]	25 years

Designer / Survey	N/A
[WTG OEM]	25 years design life
[Developer]	Up to 25 years is expected for our upcoming projects. We don't expect this to change.
[Developer]	25 -28 years to allow for installation and decommissioning of the assets
Discuss what you see as the main barriers to increasing the design life of your turbines and/or wind farms, in particular, whether you think it is likely that design life will extend beyond 20 or 25 years.	
[WTG OEM]	Based on the approach taken by the certifying authorities
[Insurance]	n/a for Insurance company
[WTG OEM]	Fatigue on foundation structures and economic balance on turbine maintenance, particularly where subsidy mechanisms have shorter timeframes.
[Finance]	Our role is to provide debt finance for offshore wind projects, hence question is more relevant for equity / project developer stakeholders. Our view on appropriate design life assumption is informed by the opinion of lenders technical advisor.
[Foundation]	Corrosion and fatigue

Designer / Survey	With turbine technology changing with bigger turbines is there a need to extend the life of a project?
[WTG OEM]	First deploy the current " next generation" (7-8 MW)
[Developer]	WTG type certificates are only recently being issued at 25 years. It seems unlikely that this will change in the coming 2-3 years. In addition the development of XL monopiles is currently close to fabrication and installation limits. Additional design life (i.e. steel) may push these beyond the point of feasibility.
[Developer]	Asset life fatigue in offshore marine environment
Considering life extension (an increase in operational life of existing projects based on maintenance and calculations) are you aware of any project considering extension beyond original design life which are already in a mature operations phase?	
[WTG OEM]	No
[Insurance]	We basically only have publicly available information
[WTG OEM]	Not aware
[Finance]	Not aware of life extension being considered by any projects but my view is industry is not mature enough at this stage for developers / owners to be giving serious consideration to this area. Repowering is being considered for some of the more mature assets which use relatively small turbines by today's standards.

[Foundation]	No
Designer / Survey	No
[WTG OEM]	Offshore wind still at an early stage.
[Finance]	Not in offshore - no
[Developer]	No
[Developer]	All of our projects are at a much earlier stage

43.3.2 Interview

Category	Interview response
[WTG OEM]	Industry is going towards 25 years, accordingly [WTG OEM] products are designed for 25 years as well. How to justify and prove justifiable life extension to only slightly change the economics of a project. Remains to be seen what will pan out in terms of design life or any life extension, as there is still a very limited experience of project more than 10 years old.

[Finance]	It is noted that there is pressure to increase design life, from a technical point of view there are arguments to extending design life. Particularly banks rather than equity will need to be convinced that there are viable parameters available for extending design life. It will be more challenging to extend design life based on the lack of sufficient track record at present. But this may change in future, and some major developers have been talking about considerably longer life. Even if a project was to extend, there is already a mismatch between design life and other constraints (for example the OFTO lease). Design of OFTO asset will have been done down to a budget, e.g. value engineered for the design life, which would be an influence when considering life extension for a site. Limited length of CFD may to an extent make life extension slightly less incentivised, although perhaps not a particularly strong effect. The way the market is for banks at present, it is a struggle to lend long term. Could foresee getting capital markets involved which would make a longer life asset more attractive. If the design life can be extended then it is likely that banks and capital market finance will step up. This could be through the long term fixed rate lenders (e.g. bond market). Bond market would like to have 20 – 30 year assets on their books, banks not comfortable with this duration for offshore wind in near future due to capital constraints.

43.3.3 Market intelligence

Evidence	Source
• Hornsea Project One is an offshore wind farm proposed by DONG Energy that will be located off the Yorkshire coast within the Hornsea Zone in the southern North Sea. The final investment decision on the Hornsea Project	http://www.power-technology.com/proje

One was taken on 3 February 2016 and the project is scheduled to be commissioned in 2020. It will have a life span of approximately 25 years.	cts/hornsea-project-one-north-sea/
• Mortenson Construction, a leader in wind energy, released a new study on May 2016 that examines turbine longevity, operations, and maintenance (O&M) challenges, and strategies that could help extend turbine lifespans up to 40 years from a 20 to 25 year design life.	http://www.windpowerengineering.com/construction/mortensen-study-identifies-strategies-improve-wind-turbine-longevity/
• Developer US Wind has begun a marine survey to prepare the final layout design involving up to 187 turbines for its 750 MW wind project in federal waters off the coast of Maryland. The $2.5bn project would be the first at utility scale in the US. DeepWater Wind's five-turbine 30MW demonstration facility off the coast of Rhode Island is due to enter commercial operation in the fourth quarter. US Wind anticipates that its project will come online in early 2020, with an operational life expectancy of more than 25 years.	http://www.rechargenews.com/wind/1442554/marine-survey-underway-for-maryland-offshore-wind-project
• According to this news article, the first electricity is expected to flow to the Polish coast from offshore wind within five years. The operational life span is planned for 25 years.	http://www.windpowerengineering.com/featured/business-news-projects/poland-gets-first-environmental-permit-offshore-

	wind/+W167:AB167 W167:AA167
• In September 2016, the Spanish technology centre Cener gave an overview of the first results coming from the testing phase on wind turbine software, the blade configurations and the control strategies developed during the European Windtrust project. The work showed that, by applying a specific configuration of flaps, it is possible to decrease the load on the blade root by at least 10%. This approach uses one flap in each blade, centred in the 90% core of the blade, with an extension of 7% in both blade span-wise directions (from 83% to 97% of the blade radius). Depending on the selected configuration and the control strategy, load reduction can be improved significantly. This opens two possibilities. The first is a reduction of the blade cost, due to a decrease of weight or a longer lifetime. The second is the use of longer blades, resulting in more power generation. Side benefits are a reduced overspeed and fewer pitch activity.	http://phys.org/news/2016-09-lifespan-turbines.html
• In September 2016, SgurrControl, part of Wood Group's clean energy business, says it has completed the two-year testing and validation of its patented Advanced Turbine Load Alleviation System (ATLAS), confirming that the solution significantly extends the life span of wind turbines by reducing blade and drivetrain loads. According to SgurrControl, on-site testing demonstrated the potential to effectively double b lade fatigue life. The 10% reduction in blade fatigue load initially modelled was validated in the test campaign. As reported, application of the findings offers even greater benefits for the life span of offshore wind turbine blades. In addition, new wind turbine designs are expected to benefit from capital cost reductions of 5%.	http://nawindpower.com/sgurrcontrol-validates-atlas-solution-to-extend-wind-turbine-lifespan
• In September 2016, German slewing bearing specialist IMO currently engineers T-Solid 4IPC pitch bearings for low-wind onshore turbines with rotor diameters in excess of 130 m and incorporating load-based IPC. Parallel efforts for 6 MW offshore turbines — including two-bladed configurations — with rotor sizes over 140 m are in	http://www.windpowermonthly.com/article/1406868/windtech-rollers-offer-

progress. The new roller-type T-Solid 4IPC bearing design focuses on comparable applications, but with an additional emphasis on enhancing operating life when combined with IPC and extended 25 year design life.	extended-lifespan-balls
• In October 2016, an article in Recharge presented the AD8-180 8 MW turbine manufactured by Adwen. The AD8-180 will fly the longest blades yet devised: LM Wind Power's 88.4P — a hybrid glass-fibre-and-carbon design bristling with innovative performance-enhancing features, including ProBlade leading-edge protection, aerodynamic energy-capture boosters known as T-spoilers and vortex generators, as well as a state-of-the-art carbon-based lightning protection system. Based on a "classic" LM two-web structure with hybridised glass-reinforced plastic and carbon reinforcement, the LM88.4P has been engineered to match 25-year design-life of the new-generation offshore turbines, with ProBlade leading-edge erosion protection extending by "a factor of five" the blade's in-field life expectancy — and so boosting offshore AEP.	http://www.rechargenews.com/wind/1443199/in-depth-adwen-8mw-poised-to-join-wind-powers-titans

43.4 Additional comments

None for this indicator

43.5 Recommendations

None for this indicator

44 UK market

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Growth and scale	UK Market	UK market

44.1 Summary Analysis

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

Finding: Behind target

Marked as 'behind target' in 2016 because fully commissioned capacity in the UK stands at 5,098 MW (as of October 2016 according to Renewable UK), well short of the 6 GW targeted by the milestones for this indicator.

There has been an announcement that the levy control framework will be extended to 2026. No firm detail on the level of budget expected to be available in each auction round or certainty of when or if auction rounds 3 and/or 4 will be held has been made available. This lack of visibility was consistently described by industry as hampering investment by the supply chain.

The announcement from Government that auction round 2 will take place in H1 of 2017 has been roundly welcomed by the industry and the budget announced is in line with what was previously expected. The announcement itself was significantly delayed.

Evidence from industry engagement consistently suggested that uncertainty caused by the impending British exit from the EU for an industry that is intrinsically linked with other EU states is damaging for long term investment in the industry.

Last year this indicator was also assessed as ‘behind target’ noting in particular that industry consultees felt that it had insufficient visibility of what the ongoing Government appetite for offshore wind would be, and what support would be available in the near and medium term. It also noted that while the UK installed capacity was increasing and that the anticipated pipeline towards 2020 of 10 GW installed capacity is behind even the ‘slow progression’ scenario of 12 GW by 2020 forecast by CRP.

The UK industry continues to voice concerns about the level of Government commitment to offshore wind, and in particular about the stability and long term visibility of ongoing support. Since the results of the first CfD auction round the industry has been given the following signals:

- Following the announcement of the results of the first CfD auction round in February 2015, the industry had expectations that further auction rounds would follow periodically, likely at 12 month intervals but no commitment had been made.
- No significant further Government comment was made until the ‘energy reset speech’ in November 2015 when it was confirmed that “if, and only if, the Government’s conditions on cost reduction are met – we will make funding available for three auctions in this Parliament.” No targets for cost reduction were described.
- The reset speech also described a Government intention to hold the first of the three auction rounds in this parliament by the end of 2016. This has not happened.
- A subsequent announcement came in November 2016 that an auction round with the originally signalled budget (£290m) will open in April 2017.

The period of over two years from the announcement of the first auction round results to the opening of a second auction round has been described consistently during industry engagement as damaging and a hindrance to investments by the supply chain which could have contributed to cost reduction.

There has also been criticism of the level of support provided to the FIDER projects, many of which will be delivered in the coming few years and will contribute to the expansion of capacity before 2020.

Outlook:

The outlook for this indicator is mixed. On one hand it looks likely that the UK will achieve around 10 GW of installed capacity by 2020 based on the existing pipeline of supported projects which are yet to be built, and based on this the industry has a reasonably good understanding of what volume the market will be for the next 3 years. However, visibility on the likely annual build out rate (or target) beyond this is uncertain.

A 'medium confidence' in the outlook for this indicator was expressed by industry. This reflects the mix of uncertainty tempered by the general expectation that there will be a reasonable size of UK development and construction pipeline for the next 5 – 10 years.

44.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	≥7 GW operational. ≤50 g/kwh 2030 decarbonisation target set. Extension of LCF beyond 2021.	≥8 GW installed. An additional 5 GW expected to deliver out to 2020, with clear expectation of at least 2 GW/year of volume beyond this	≥9.5 GW. expectation of at least 2 GW/year of volume beyond this	≥11 GW installed. Expectation of at least 2 GW/year of volume beyond this	≥13 GW installed. Expectation of at least 2 GW/year of volume beyond this
On target	≥6 GW. ≤100 g/kwh 2030 decarbonisation target set. Extension of LCF beyond 2021.	≥7Gw installed. An additional 4 GW expected to deliver out to 2020, with clear expectation of at least 1 GW/year of volume beyond this	≥8 GW. Expectation of at least a	≥9.5 GW. Expectation of at least 1 GW/year market 2020-2024	≥11 GW installed. Expectation of at least a 1 GW a year delivered over next five years

Behind target	≥6 GW. No decarbonisation target or ≥200 g/kwh 2030 decarbonisation target set. Extension of LCF beyond 2021.	≥6 GW installed. An additional 3 GW expected to deliver out to 2020, with clear expectation of at least 0.5 GW/year of volume beyond this	≥7 GW. Expectation of at least a 0.5 GW/year market 2020-2023	≥9 GW. Expectation of at least a 0.5 GW/year market 2020-2023	≥10 GW Expectation of at least a 0.5 GW/year market 2020-2023
Missed target	Financial support available likely to support 6 GW by 2020. No visibility beyond that	No 2030 decarbonisation target set. Financial support available likely to support 6 GW by 2020. No visibility beyond that	Financial support available likely to support 6 GW by 2020. No visibility beyond that	Financial support available likely to support 6 GW by 2020. No visibility beyond that	Financial support available likely to support 6 GW by 2020. No visibility beyond that

44.3 Evidence

44.3.1 Questionnaires

Category	Questionnaire response
What offshore wind capacity (GW/year) on average do you expect the UK to add in the next 3 - 5 years?	
[WTG OEM]	1-1.5 GW/yr
[O&M]	1 GW

[WTG OEM]	Government has been clear that it expects 10 GW across next decade so 1 GW/year.
[Finance]	c. 750 MW 1 GW/year
[Foundation]	1 GW / year
[Blades]	1.2 GW/year
Designer / Survey	Hopefully 1-1.5 GW per year
[WTG OEM]	10 GW/year cumulative by 2020 expected
[Finance]	1 GW
[Installation]	1-2 GW
[Developer]	The UK should add around 1 – 1.5 GW per year from 2017 - 2020
Do you have expectations that the size of the UK market in offshore wind will change (expand/contract) or remain flat in your sector in the next 3 - 5 years. Please explain your reasoning.	
[WTG OEM]	It will remain flat. It's all dependent on the CfD auction winners and ensuring that projects are consented on time

[O&M]	Expand
[WTG OEM]	There is already a string pipeline of projects (5GW) which has reached FID and is in build before 2020 - so slightly higher build rate in next 3 years
[Finance]	Broadly remain flat due to the mixed messages from UK Government on offshore wind (significance of its role in the energy generation mix going forward is difficult to predict). For instance, delay of next CFD auction creates uncertainty and negatively impacts investor confidence in UK.
[Foundation]	Flat
[Blades]	FLAT
Designer / Survey	Currently we see our market as flat, although without further CFD and government vision on the future of OWF this might contract.
[WTG OEM]	Three auctions expected. Announcements awaited.
[Finance]	Contract. Due to limited visibility in the long term plans of government to support this sector.
[Installation]	Everything is riding on the governments impending announcement surrounding the AR2 CfDs. What is the size of the pot going to be? When will it be available? The industry and developers require certainty above all else as to timelines and volumes of CfDs that will be available. If the government delays a decision any further it will negatively impact the UK

	market size moving forward. There is only so much speculative risk the developers are going to be willing to take without sight of a clear policy for the years to come.
[Developer]	It will expand due to growth in capacity form 5 GW – to 11 GW by 2020

44.3.2 Interview

Category	Interview response
Do you have expectations that the size of the UK market in offshore wind will change (expand/contract) or remain flat in your sector in the next 3 - 5 years. Please explain your reasoning.	
[O&M]	In terms of the O&M market, [O&M] are expecting a steady increase in work. There is a big requirement for blade technicians and a continued growth in need for blade care. [O&M] expect to see consolidation in the Independent Service Provider market as current situation involving many ISPs offering bespoke services for small bits of work will not be sustainable. The need to drive down costs in the supply chain, the complexity of frameworks and the significant costs of training will chew up smaller companies and drive the need for consolidation. For example a blade repair company may partner with a vessel provider.
[WTG OEM]	Word of introduction, from personal point of view, offshore wind is still seen as being of strategic value to [WTG OEM]s, and so are active in the UK and in Germany and are actively pursuing projects. [WTG OEM] have won an order in Germany, details in questionnaire response.

	[WTG OEM] are looking forward to see what comes out of the next auction rounds and expect a CFD auction in the UK early in 2017. There is an expectation that projects in the UK will bid with an extremely attractive price well below £100/MWh in the next CfD auction round. There is a pent up demand of projects in the UK that have been consented but have not had a chance to bid for a support auction, these projects in particular will almost desperate to have the chance to bid for support, and it will therefore be important to see when and if subsequent rounds appear after the auction that now looks likely in H1 2017.
[Foundation]	Reflection is that quite a lot of interesting stuff has been happening in last 4 months in Denmark and Netherlands that will impact UK market in future, expect to discuss this throughout the interview.
[Foundation]	Developers in the UK, taking for example [PROJECT] is a huge project and has seen a lot of upfront investment. The level of this individual development cost that developers have currently accrued may be one reason why the industry does not expect that CfD will in the UK mean as aggressive a cost reduction as seen elsewhere in Europe is possible in the UK. Another big influence on developer's appetite could be Brexit. Interviewee personal opinion is that they expect a delay in the speed of how quickly cost reductions can be implemented, this could mean that developers are more conservative on UK projects and do not see cost reductions at a similar rate.
[Installation]	A lot of expectation in how low next auction prices in the UK will be, particularly when reflecting on how low recent EU bids have been, even when considering the differences between the two, [PROJECT] which at the time looked like a record low now within 18 months almost looks like an expensive project by comparison.
[Developer]	There is an expectation that we will now get to 10 GW of installed capacity fairly easily

	The big question is what happens beyond that, which will really come down to government appetite. It may not continue to work long term if annual auctions are announced only 1 year in advance, The longer term visibility of government desire for offshore wind is required if we expect to continue to see investment by companies in development of new technologies and new sites. There may well be projects in the UK which are in the position that are waiting for support, and due to the highly competitive nature of what next support might be released there may well be semi obsolete projects in the UK at present waiting for some support in some future round(s).
[Developer]	We use Bloomberg data
[Foundation]	Confidence in the future of the UK and EU market is fairly neutral. There should be a good volume of work available for the supply chain from projects reaching FID in 2017. However the overall continuity and volume is still a concern. Without the clear volume and certainty of projects, it is difficulty to drive the innovation and efficiencies. As a result of this uncertainty we are likely to see more consolidation in the supply chain. New markets in France will help to ensure there is sufficient competition.
[O&M]	Engagement with the supply chain is now happening pre-CFD as opposed to post-CFD in previous years. This is a feature of a more mature sector. Contracting over the last three years has become more complex and the industry could benefit from some commercial innovation of contracts in order to get the costs down. Finance and contracting can contribute to LCOE reduction as much as technology improvements.
[Finance]	In terms of timing the recent announcement by government of auction rounds is generally as was previously expected.

	In terms of budget the industry have been pleasantly surprised, it was probably broadly as expected or possibly even slightly higher Influence of fuel technologies is unknown, but even at 'low' trend for offshore wind this budget could support at least ~1.4 GW of offshore wind which has been warmly received by the market. There is uncertainty about how competing (e.g. fuel technologies) will behave in this auction round, could get approaching almost 2 GW of offshore wind at a stretch based on the unknown behaviour of others. Fuel technology projects may hang on for 'subsidy free' which would mean they may play a small part towards the next round.
[Blades]	The requirement for government support will fall away and pure market forces will take over, perhaps slower than onshore but in say 10 years would expect that offshore wind will not require any subsidy, and that by around 2025 it will be possible to deliver offshore wind at the market price of electricity.
[Blades]	Are considering investment in a blade production factory in the UK, this would allow exporting of blades to EU and eastern seaboard of USA. Recent announcement of continued government support will give some certainty and makes it easier to justify bringing manufacturing to the UK for offshore wind. Would like to have a baseload of demand for manufacture in the UK and with current pound values exporting could look attractive/competitive. Very hopeful that offshore wind is increasingly becoming more competitive, recent strike prices in Europe are delivering LCOE very close to and very competitive with onshore wind and other generation technologies.

44.3.3 Market intelligence

Evidence	Source
• On the 3rd February 2016, DONG Energy made a Final Investment Decision to build the 1.2 GW Hornsea Project One offshore wind farm, the world's first park to exceed 1000 MW. The multi-billion pound project was one of eight renewable energy projects to sign contracts under the Final Investment Decision Enabling for Renewables (FIDER) process of the Energy Market Reform (EMR).	4c Offshore Market Overview August 2016
• CS Wind UK, the Campbeltown wind turbine tower steel fabricators employing 170 local people, and Vattenfall, the Swedish state-owned wind farm developer, are to sign a Memorandum of Understanding (MoU) committing both to co-operation over potential future contract and supply opportunities for Vattenfall's UK development pipeline. CS Wind UK is due to break ground on a major new £27 million investment on Thursday 7 July at the 15 year old facility. The investment will increase production volume for onshore wind and allow for the fabrication of larger diameter towers for the offshore wind sector. The facility upgrade follows the acquisition in April this year of Wind Towers (Scotland) by the South Korean manufacturer CS Wind Corporation.	https://corporate.vattenfall.co.uk/about-vattenfall/news-and-media/press-releases/2016/wind-energy-agreement-confidence-booster-for-sector/
• According to Business Green, FT paper reported on 25th of August 2016 that the auction, which had been planned for this autumn, has seen its timetable slip as ministers continue to work on merging the Department of Energy and Climate Change (DECC) and the Department for Business, Innovation, and Skills into the new Department for Business, Energy, and Industrial Strategy (BEIS).	http://www.businessgreen.com/bg/news/2468895/reports-offshore-wind-farm-auction-delayed-as-hinkley-rumours-continue

• In September 2016, the UK government announced that it expects to confirm the final allocation framework and budget for the next Contracts for Difference auction ‘within weeks’.	renews344, 4C Offshore Market Overview August 2016
• In the same month, NKT Cables is to market a full transmission manufacturing and installation package to offshore wind developers after tying up an €836m deal to acquire ABB’s high-voltage cable business.	renews344
• Scottish Power is on course to place a record £3bn-plus of contracts this year as the utility pours investment into onshore and offshore wind farms, major grid upgrades and the roll-out of smart meters.	renews343
• BEIS has confirmed its intention to extend the delivery timeline of Contracts for Difference to 31 March 2026 from 31 March 2020. Former Energy Minister for the Department of Energy and Climate Change (DECC) Amber Rudd committed to three conditional offshore wind auctions by the end of the decade subject to cost reductions and suggested that a total of 10 GW could be procured during the 2020s if offshore wind becomes cost-competitive. This news followed a significant delay in the announcement of a second Contracts for Difference (CfD) allocation round, which was initially pinpointed for Q3 2015 following success of the first round that concluded earlier in February this year where over 1 GW of offshore wind secured subsidies. Following the UK government decision to completely remove subsidies for onshore wind, the announcement of future tender rounds will bring some reassurance to the offshore industry although developers will be eager to learn the exact conditions associated with the plans.	renews343, 4c offshore Market Overview August 2016
• On 26/09/16 DONG Energy has announced plans to build what it claims will be the UK's largest offshore wind operations and maintenance hub in Grimsby to support its work in the region. Subject to planning approval, the new multi-million pound hub is set to be developed in the town's Royal Dock and will initially support DONG's	http://www.businessgreen.com/bg/news/2471963/dong-energy-announces-multi-

Westermost Rough, Race Bank and Hornsea Project One offshore wind farms, the Danish energy firm announced on Friday.	million-pound-grimsby-offshore-wind-hub
• UK regulator Ofgem will launch a tender on 10 October for companies to bid to own five transmission links worth about £2bn that will be connected to offshore wind farms. The fifth tender for offshore transmission owners (OFTOs) run by Ofgem includes links to the Dudgeon, Galloper, Race Bank, Rampion and Walney Extension wind farms. The regulator will select the most competitive bids to own and run the links for to offshore sites for a period of 20 years. This fifth tender round comes after the Ofgem recently shortlisted five bidders to own and run the £230m transmission link for the Burbo Bank Extension offshore wind farm in the Bay of Liverpool.	http://energyinfrastructure.cleantechnology-business-review.com/news/ofgem-to-start-5th-tender-rounds-of-electricity-transmission-for-uks-offshore-wind-farms-031016-5021564

44.4 Additional comments

None for this indicator

44.5 Recommendations

None for this indicator

45 EU market (including UK)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Growth and scale	EU Market (including UK)	EU market (including UK)

45.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Behind target	⇨	Medium confidence

Finding: Behind target

Marked as 'behind target' in 2016 because fully commissioned capacity in the Europe stands at 10,996 MW (as of October 2016 according to Renewable UK), which is short of the 12 GW targeted by the milestones for this indicator.

There is an expectation that an installed capacity of around 25 GW will be achieved by 2020.

The volume of capacity which will be added in 2020 and beyond is uncertain, maintaining a pipeline of projects at a volume of ~3 GW per year as suggested by the on target milestones for this indicator will require that markets to date which have provided only small amounts of development will commit to deployment on a larger scale. Current forecasts show a trend of reducing capacity installation by the UK and Germany (which currently dominate) towards the start of the next decade and suggest that projects in France and the Netherlands will contribute significantly greater capacity additions than has been the case to date.

Last year this indicator was assessed as ‘behind target’ noting that although installed capacity was slightly ahead of what was anticipated, there was not a sufficient size of anticipated pipeline to 2020.

Several participants also highlighted the clear political aspirations (and associated commitment to investment, facilities and supporting industries – e.g. ports) which exists in other EU markets. They pointed out that a significant part of the cost reduction demonstrated by recent EU strike price announcements has been contributed by a Government level enthusiasm and support for offshore wind that they felt was lacking and hence hampering cost reduction in the UK.

Outlook:

Industry organisations (such as WindEurope and RenewableUK) forecasts for future pipeline of EU capacity remain bullish, and generally there is an expectation that 25 GW of installed capacity will be achieved. Industry engagement also revealed a theme of positivity about the ongoing success and size of the EU market, and with some clear indications that there are expected to be emerging markets into which the EU supply chain will expand in the coming 5 – 10 years.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, with a generally positive feeling that there would continue to be significant year on year development in the EU market capacity.

45.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	≥15 GW installed. Expectation of 28 GW by 2020 and 4 GW/year market beyond that.	≥18 GW. Expectation of 28 GW by 2020 and 4 GW/year market beyond that.	≥22 GW installed. Expectation of 28 GW by 2020 and 4 GW/year market beyond that.	≥25 GW installed. Expectation of 28 GW by 2020 and 4 GW/year market beyond that.	28 GW installed. Expectation of 28 GW by 2020 and 4 GW/year market beyond that.

On target	≥12 GW installed. Expectation of 25 GW by 2020 and 3 GW/year market beyond that.	≥15 GW. Expectation of 25 GW by 2020 and 3 GW/year market beyond that.	≥18 GW. Expectation of at least a 3 GW/year market post 2020.	≥22 GW. Expectation of at least a 3 GW/year market post 2020.	≥25 GW.Expectation of at least a 3GW/year market post 2020.
Behind target	≥10 GW. Expectation of 22 GW by 2020.	≥12 GW. Expectation of 22 GW by 2020 and 2 GW/year market beyond that	≥15 GW. Expectation of at least a 2 GW/year market	≥20 GW. Expectation of at least a 2 GW/year market post 2020	≥22 GW. Expectation of at least a 2GW/year market post 2020
Missed target	Expectation of less than 20 GW/year by 2020 and less than 1.5 GW/year beyond that	Expectation of less than 20 GW/year by 2020 and less than 1.5 GW/year beyond that	Expectation of less than 20 GW/year by 2020 and less than 1.5 GW/year beyond that	Expectation of less than 20 GW/year by 2020 and less than 1.5 GW/year beyond that	Expectation of less than 20 GW/year by 2020 and less than 1.5 GW/year beyond that

45.3 Evidence

45.3.1 Questionnaires

Category	Questionnaire response
What offshore wind capacity (GW/year) on average do you expect the European market to add in the next 3 - 5 years?	
[WTG OEM]	2-3 GW/year

[O&M]	1.5
[WTG OEM]	3-4 GW
[Finance]	c. 3 GW/year
[Foundation]	2 GW/year
[Blades]	10 GW/up to 2021
Designer / Survey	2-3 GW
[WTG OEM]	3-5 GW/year expected in Europe per industry analysts
[Finance]	3 GW
[Developer]	Average of 3 GW/year – 2016 - 2020
Do you have expectations that the size of the European market in offshore wind will change (expand/contract) or remain flat in your sector in the next 3 - 5 years. Please explain your reasoning.	
[WTG OEM]	Remain the same. Analysis based on individual country data and projections

[O&M]	Expand
[WTG OEM]	All markets not managing to avoid 'Stop-start' deployment so very peaky project profiles. Politics drives deployment.
[Finance]	Expand. Current auction processes (Netherlands, Denmark, UK(?)), combined with the near term pipeline in Germany and Belgium and in the medium term the addition of offshore wind in France should support expansion of the European offshore wind market.
[Foundation]	Expand
[Blades]	It will expand
Designer / Survey	For us it is also flat but we hope to gain business in new markets such as O&M.
[WTG OEM]	Clear roadmap in Germany and the Netherlands
[Finance]	Expand. Recent low pricing will encourage new markets to enter. Also, developed markets may just expand their programs (e.g. Netherlands).
[Installation]	I believe growth is on the cards - with Baltic states and new markets emerging where there previously was no or little movement.

[Developer]	EU market expected to grow from around 1 GW in 2015 to 27 GW in 2020
Have you been involved in any non-European offshore wind projects? What is your outlook for international market volumes in the next 3 - 5 years? Please explain your reasoning.	
[WTG OEM]	Yes. Increasing volumes of non-European offshore wind
[O&M]	Yes. Slow unsteady growth, however China is growing fast.
[WTG OEM]	Yes - Block Island in US, projects in Taiwan and China. Both emerging markets so low volumes short term but large potential in US in particular
[Finance]	Not involved in any non-European offshore wind projects at this stage. My expectation is that the US market will grow in the next 3-5 years on the basis of the activity I am beginning to see there (for example Block Island reaching financial close, [Developer]'s expansion into the US are indicators of growth in the short to medium term), followed by the Asian market.
[Foundation]	No
[Blades]	Yes, china offshore market will become very big.
Designer / Survey	Yes we have worked in Taiwan and now also in US East coast, we see both markets as growth areas although the pace of development is still a bit uncertain.

[WTG OEM]	China is a market, with delays. Taiwan has clear targets. Korea, Japan may move forward in next decade. US expected to move forward in next decade. First projects expected in India in next decade.
[Finance]	Yes - japan. Increase. Clearly China, Japan, Taiwan and the States are markets that will develop in the next few years.
[Installation]	No
[Developer]	We have pre-qualified for some non EU auctions previously though have not participated. The largest market out with the EU is expected to be China with capacity forecast to grow from around 1 GW to 11GW by 2020

45.3.2 Interview

Category	Interview response
Do you have expectations that the size of the European market in offshore wind will change (expand/contract) or remain flat in your sector in the next 3 - 5 years. Please explain your reasoning.	
[O&M]	[O&M] expect to see similar growth trend to the UK O&M market and foresee continued growth for the next 3-5 years.

	International markets are now opening up. [O&M] have now opened an office in the USA to capitalise on one of these new markets.
[WTG OEM]	All countries in Europe are tending to move towards auction based support mechanisms. As a key supplier, [WTG OEM] feel a lot of pressure to reduce LCOE for their products from their customers, costs and cost reduction is evidently key on a lot of people's lists.
[Foundation]	In general it is expected that we are going to see a gap in the market from 2020 to 2022 associated with change in support regulations, particularly in Germany. That is the projects which can and will be built between now and ~2020 are almost all already designed and committed and the pipeline is fairly well understood. However as there has been something of a hiatus on getting the next batch of projects off the ground/supported this will translate to a gap in installations in the future. Environmental regulations will continue to challenge the foundation installation, and particularly monopile industry. This is a consideration that makes many EU countries a prime market for them because suction buckets do not have the same installation noise issues as monopiles. There is a general expectation that regulations in other markets e.g. Denmark, Netherlands and UK may follow German lead and see limits around piling noise will continue to tighten up. The main driver of what the supply chain in foundations will see coming as a market and future pipeline will be driven by the requirement for bidding and auctioning of support contracts, i.e. in Germany. Projects going to 2020 in Germany are steady and committed, but the move to a new support framework will mean that there is a gap in project pipelines. Support contracts based on fixed power price mean that developers have for a long time had a very good set of conditions where investment and technology risk combined to make offshore wind profitable and a very attractive proposition. Recent low prices have shown how much developers have been making on their investment. In future projects that bid low power prices to win auction support can either take a lower margin, which looks unlikely and may mean some

	projects/investments are not viable, or they will look to do some smarter things to get cost out, such as looking at novel foundations.
[Developer]	For the next couple of years there is a lot more certainty in the market in Europe compared to UK, in general there are more vocal and obvious discussions about when and how offshore wind is expected to develop/contribute in the EU countries. Medium term there is no reason to expect that there will be more or less certainty in the EU market. There are different development models in EU, and some of those really reduce the risk for the developer, which is not the model in the UK. French offshore is a new beast, there are some issues with challenges to consent and things are taking a long time as they are going up a steep learning curve for developing sites there. Legislation in France does not consider reasonable limits and practicalities on consenting, there is obvious short and near term risk that a developer in France will have to deal with that is associated with the uncertainty. There is a clear long term intention in place in France, and a clear central government desire for a future pipeline of known size, which can give some comfort in contract to the risks. [Developer] has won first floating round in France, target FID in 2019, fairly large ~30 MW project. More a technology watch than active project but are continuing to look at what floating projects in the future. [Developer] do believe as a company that floating can come down the cost curve to be competitive, but this would require significant government appetite to do that. In the UK there is not a sufficient scarcity of suitable sites for fixed foundations to really drive much demand for floating. Floating will likely happen, but unlikely to be in the UK seriously for some time.

[Insurance]	Operations insurance in the European market is massively different to the UK. Clients in the UK are more likely to buy business interruption coverage due to the OFTO regulatory mechanism. In Germany for example, they are reimbursed for any losses so insurance products tend to not include as much business interruption coverage. Comparing Germany to the UK there is no continuous business interruption market. This makes the UK insurance market less competitive in the UK than Germany.
[Foundation]	Confidence in the future of the UK and EU market is fairly neutral. There should be a good volume of work available for the supply chain from projects reaching FID in 2017. However the overall continuity and volume is still a concern. Without the clear volume and certainty of projects, it is difficulty to drive the innovation and efficiencies. As a result of this uncertainty we are likely to see more consolidation in the supply chain. New markets in France will help to ensure there is sufficient competition.

45.3.3 Market intelligence

Evidence	Source
• Dong Energy, the biggest operator of offshore windfarms in Britain, has said it plans to spend a further £6bn in the UK by 2020, convinced that the government is serious about supporting wind power.	https://www.theguardian.com/business/2016/jan/03/major-offshore-wind-operator-plans-6bn-uk-pound-investment-2020

• In July 2016, Reuters stated that the British offshore wind industry, already bruised by subsidy changes, faces uncertainty after Britain voted to leave the European Union, with investors worried about future government incentives, exchange rates and export duties.	http://uk.reuters.com/article/uk-britain-eu-renewables-idUKKCN0ZH4CZ
• In October 2016, it was announced that GE is buying LM Wind Power for €1.5bn. The Danish blade manufacturer, which is already a supplier to the US company both onshore and offshore, will continue to operate as a standalone business.	renews345
• On 15/09/2016 Statoil is planning to bid the 1.2 GW Creyke Beck A wind farm off the Yorkshire coast into the next Contracts for Difference auction.	renews343
• Reuters reported that investors in the offshore wind market are switching their sights to the United States as future support for the industry in Europe remains uncertain, leaving billions of euros looking for a new home. The shift in focus comes as three states on the U.S. east coast -- Massachusetts, New Jersey and New York -- are auctioning leases on hundreds of thousands of acres for offshore wind farms, drawing interest from leading European companies. Europe has led the way in developing offshore -- the most expensive form of renewable energy -- but few of the continent's cash-strapped governments have given firm plans for support beyond 2020 for a sector still dependent on subsidies.	http://uk.reuters.com/article/uk-europe-offshore-windpower-idUKKCN11T125
• On 18/10/16 an article in Energy Voice stated that the UK is now the world's largest offshore wind market accounting for more than 40% of the installed capacity, according to new research. The Global Wind Energy Outlook said Germany is in a close second spot with 27%. In its latest report it was found a combination of wind and solar provided Germany with nearly 100% of its power needs. On a stormy day in August, wind turbines in Scotland generated more electricity than the entire country used on that day. The largest market outside Europe is now China which accounts for approximately 8.4% of the global market. It	https://www.energyvoice.com/otherenergy/121959/uk-now-worlds-largest-offshore-wind-market/

was found China's cumulative wind power installations at the end of 2015 are more than all European Union countries combined. Last year, nearly 1.1 million people were employed by the global wind power industry. The report also said by 2030 wind power could reach 2,110 GW and supply up to 20% of global electricity, creating 2.4 million new jobs and reducing CO^2 emissions by more than 3.3billion tonnes per year, and attracting annual investment of about €200billion. It said wind is the cheapest way to add capacity to the grid in a large number of markets, becoming the utility option of choice. In the US, the cost of wind energy has dropped by more than 65% in the past six years.	

45.4 Additional comments

None for this indicator

45.5 Recommendations

None for this indicator

46 Competition in turbine supply

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the industry	Turbines	Competition in turbine supply

46.1 Summary Analysis

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

Finding: Behind target

Marked as 'behind target' in 2016 because consolidation has reduced the number of competing turbine OEMs and there are not at present 4 OEMs with 'proven' turbines available on the market. For clarity proven throughout all three CRMF studies to date has been defined as a turbine product which has all three of:

- 250 to 400 turbine-months of satisfactory accrued operational experience;
- 24 to 36 month of satisfactory operational experience on first prototype; and,
- 12 to 24 month of satisfactory operational experience from a high energy site.

The market for turbine supply is dominated by Siemens, with all other UK projects going to MHI Vestas. There is no evidence to suggest that any project in the near to medium term will select a turbine for a UK project from outside of these two suppliers who can demonstrate significant track record. The level of competition (if judged by the number of players) is therefore low.

The consolidation of Gamesa and Siemens has effectively taken a potential new entrant (Adwen) out of the running for any projects in the near future, with the final fate of existing and development Adwen turbine platforms currently uncertain.

Senvion have announced successful contract win for a project in Germany.

GE have delivered turbines (in the USA) and are expected to supply turbines to EU projects (in France) around the end of the decade.

New entrants with radically different turbine concepts exist (2B Energy have progressed to installation of a prototype) but their route to market for UK projects looks uncertain. There is an outside possibility of other new low cost entrants to the European offshore wind market, but again route to market based the desire of financing to support low risk projects currently looks unlikely. Samsung have notably abandoned plans to compete in offshore wind turbine supply.

Last year this indicator was assessed as ‘on target’ noting that there were 4 OEMs with products on the market and an offshore track record but that Siemens dominates. CRMF 2015 also suggested that only 3 OEMs were offering turbines which met the definition of ‘proven’ products and also that only 3 OEMs had signed contracts to supply projects reaching FID in the EU in 2015.

Outlook:

The supply of turbines for projects to 2020 is likely to continue to be dominated by 2 OEMs. The possibility of further consolidation or exit remains but there is not expected to be a significant change in the level of competition with almost universal consensus from engagement that the current level of competition in turbine supply is not likely to change in the near future.

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 as turbine OEMs consolidate.

46.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>3 OEMs with "proven" products active in the market	>4 OEMs with "proven" products active in the market	>4 OEMs with "proven" products active in the market	>4 OEMs with "proven" products active in the market	>4 OEMs with "proven" products active in the market
On target	4 OEMs with "proven" products active in the market. At least one other OEM starts to install new turbines	4 OEMs with "proven" products active in the market, including successful commissioning and operation of new OEMs product	4 OEMs with "proven" products active in the market	4 OEMs with "proven" products active in the market	4 OEMs with "proven" products active in the market
Behind target	2 OEMs with "proven" products active in the market. At least one other OEM starts installing turbines on commercial project	3 OEMs with "proven" products active in the market, including new entrant having commissioned commercial scale project	3 OEMs with "proven" products active in the market	3 OEMs with "proven" products active in the market	3 OEMs with "proven" products active in the market
Missed target	1 OEM with "proven" products active in the market	1 OEM with "proven" products active in the market	1 OEM with "proven" products active in the market	1 OEM with "proven" products active in the market	1 OEM with "proven" products active in the market

46.3 Evidence

46.3.1 Questionnaires

Category	Questionnaire response
How many turbine OEMs would you consider to have proven offshore wind turbines available to the market?	
[WTG OEM]	3
[WTG OEM]	[WTG OEM] are the only manufacturer with proven 6 MW class machines today. [WTG OEM] have 8 MW at 0 series (first commercial deployment) as do [WTG OEM].
[WTG OEM]	Five
[Developer]	4
[Developer]	5
Describe how you select or qualify turbines for your projects. In particular referencing track record, prototypes, certification, value and availability.	

[Developer]	All of the above, we also consider local market industrial impact and existing relationships
Do you expect to qualify any new turbines in the next few years. For example have you placed contracts for the supply of any yet to be proven turbine models? If so please provide details.	
[Developer]	No
[Developer]	We have chosen to use new models on previous projects ahead of type certification being received. WTG technology will continue to develop and we expect this will also recur in the future. What is important is that the technology is then tested and proven ahead of actually being deployed.
How would you rate competition in the supply of offshore wind turbines?	
[WTG OEM]	The market is consolidating so the number of suppliers is decreasing.
[WTG OEM]	Adequate - its not a massive market any more so supporting 3-4 turbine OEMs is realistic.
[WTG OEM]	Sufficient competition ensuring sustainable industry
[Developer]	Competition is limited in the 6-10 MW class. Further compounded by the [WTG OEM] and [WTG OEM] current status.

[Developer]	Competitive
Do you see this improving over the next three years?	
[WTG OEM]	No
[WTG OEM]	No
[WTG OEM]	No
[Developer]	No
[Developer]	No – will stay the same or decrease

46.3.2 Interview

Category	Interview response
How many turbine OEMs would you consider to have proven offshore wind turbines available to the market?	

[WTG OEM]	Customers of turbine OEMS have demonstrated a large risk appetite in the past, for example [WTG OEM] had a proven 5 or 6 MW but [Developer] and others were happy to take a risk on unproven 7/8 MW designs when they were not even being demonstrated, and make decisions to use them at a large scale. A lot of the appetite for risk is dependent on where the money for a project is coming from e.g. [Developer] structured in such a way that allowed them to mitigate risk of going straight to a new unproven design and still have a successful project. [Developer] have almost co-developed the [WTG OEM] 8 MW machine, developers are picking turbine OEMs to work with very early and picking who they want to be a winner at a very early point
[Developer]	There may not be enough players for healthy competition. When negotiating TSA for round 1 sites there was very little competition and little room for negotiation There is now some competition, the supply chain have been quite dynamic and reactive. It was looking for a time like a 5 – 6 OEM world, but now moving back to more like 3 max. Could be a catch 22 situation, the industry wants competition, but who is willing to take the risk on an unproven and new technology to bring a new OEM along? More competition would be nice but may not be realistic. 3 suppliers could possibly be enough. Comparing to onshore, [Developer] would tend to work with 3 – 4 well established OEMs, and in a way they don't want a huge number of suppliers, as relationships and experiences is difficult to build up if every project uses a new supplier. International supply chain; due diligence is so deep that it looks unrealistic that far away manufacture or low cost entrants look likely. [Developer] would more likely target being the 2nd or 3rd adopter if some low cost entrants were to come in, difficult to see who would take the risk first.

46.3.3 Market intelligence

Evidence	Source
• In September 2016, it has been confirmed that Gamesa, soon to be merged with Siemens, will buy the rest of Adwen, the 50/50 joint venture between Areva and Gamesa, for €60m ($67.4m), giving it full control of the offshore OEM under the terms of the wider merger agreement announced between Siemens Wind and Gamesa in June. Germany-based OEM Senvion was also looking into Adwen, but later pulled out of the race. As Adwen will end up in the same company as Siemens once the merger has received a green light from Gamesa shareholders and the Spanish stock market regulator, European competition regulators will likely need to take a closer look, as the addition of Adwen would widen Siemens' already overwhelming share of the European offshore wind turbine market. Siemens turbines accounted for about 60% of European offshore installations in 2015, according to data from industry body WindEurope, with Adwen taking an 18.2% share. MHI Vestas, GE and Senvion are the other major offshore wind players active in Europe. Writing in Recharge last week, BVG Associates argues that if the Gamesa deal for Adwen is waved through, it could indirectly lead to the shrinking of the market to three by putting pressure on Senvion's position. The deal directly removes one name from the list, Adwen. It potentially also drives Senvion from the market. Two years ago, there were six (Alstom, Areva, Gamesa, MHI Vestas, Senvion and Siemens); now, surely we risk heading for three – GE, MHI Vestas and Siemens-Gamesa.	http://www.rechargenews.com/wind/1444944/opinion-gamesa-deal-for-adwen-risks-offshore-market-of-three
• General Electric Co. plans to buy a maker of wind-turbine blades for $1.65 billion, bolstering the renewable-energy business that has become a central focus of the industrial giant. Acquiring Denmark-based LM Wind Power -- maker of the blades mounted to the GE turbines of the Block Island Wind Farm -- would enhance GE's ability to serve customers in the onshore and offshore wind markets, the companies said. GE plans to	http://www.rechargenews.com/wind/1445362/siemens-wind-ceo-no-competition-issues-in-

operate LM Wind Power, which is owned by private-equity firm Doughty Hanson, as a standalone business within the renewable-energy unit.	offshore-post-adwen-deal

46.4 Additional comments

None for this indicator

46.5 Recommendations

None for this indicator

47 Competition in support structure supply

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the industry	Support structures	Competition in support structure supply

47.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016 because there are several distinct organisations winning contracts and delivering monopile and jacket foundations from locations across Europe. This indicator is close to being assessed as ‘ahead of target’ as the level of competition was evidenced by engagement and the number of credible players to be healthy. There is however limited evidence of influences of low cost entrants (from outside of Western Europe) on the level of competition, justifying the decision not to move this indicator to ‘ahead of target’ despite good levels of competition.

Last year this indicator was also assessed as ‘on target’ noting generally adequate levels of competition in both jacket and monopile supply.

Outlook:

In the coming years it is likely that there will be significant demand (tending towards under-supply) for jacket foundations in particular, as a number of projects which have committed to use jackets will have overlapping programmes. This trend coupled with the desire for Developers to split foundation supply contracts to spread risk could see some contracts for jacket foundations to be placed outside of Europe in the next few years.

Similarly, production of ever larger monopile foundations will challenge the capabilities of some fabricators, and if all monopile projects in future seek to use ~10 m diameter piles weighing over 1000 t then there could be a reduction in the level of competition as the number of capable fabricators is smaller, and the investment required in plant is prohibitive in comparison to the potential available market size.

The volume of UK manufacturing of support structures in future is not certain.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, reflecting generally positive progress with the existence of some constraints and potential pinch points which could challenge competition.

47.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>5 active monopile suppliers with 1 low cost competitor. 4 or more jacket suppliers	>6 active monopile suppliers with 1 low cost competitor with 4 or more jacket suppliers	>6 active monopile suppliers with 1 low cost competitor with 4 or more jacket suppliers	>6 active monopile suppliers with 1 low cost competitor with 4 or more jacket suppliers and 2 GBS manufacturing facilities with proven designs	>6 active monopile suppliers with 1 low cost competitor with 4 or more jacket suppliers
On target	3-5 active monopile suppliers with 1 low cost competitor.	4-6 active monopile suppliers capable of manufacturing larger	4-6 active monopile suppliers capable of manufacturing larger	4-6 active monopile suppliers capable of manufacturing larger	4-6 active monopile suppliers with 1 low cost competitor. 2-3

	Another monopile supplier develops capability to enter market through expanding factory. 2-3 jacket suppliers	monopiles with 1 low cost competitor. 2-3 jacket suppliers with purpose built factories	monopiles with 1 low cost competitor. 2-3 jacket suppliers with purpose built factories. GBS manufacturing facility reaches FID	monopiles with 1 low cost competitor. 2-3 jacket suppliers with purpose built factories. GBS facility under construction	jacket suppliers with purpose built factories. At least one GBS supplier with demonstrated technology.
Behind target	<3 active monopile suppliers with no low cost competition. 2 jacket suppliers with purpose built factories	<4 active monopile suppliers with no low cost competition. 2 jacket suppliers with purpose built factories	<4 active monopile suppliers with no low cost competition. 2 jacket suppliers with purpose built factories	<4 active monopile suppliers with no low cost competition. 2 jacket suppliers with purpose built factories. No manufacturing facility for GBS	<4 active monopile suppliers with no low cost competition. 2 jacket suppliers with purpose built factories
Missed target	3 active monopile supplier. 1 active jacket supplier	<3 active monopile suppliers. 1 jacket supplier	<3 active monopile suppliers. 1 jacket supplier	<3 active monopile suppliers. 1 jacket supplier	<3 active monopile suppliers. 1 jacket supplier

47.3 Evidence

47.3.1 Questionnaires

Category	Questionnaire response
How many suppliers of monopiles would you consider are active in the market?	

[Foundation]	3
Designer / Survey	Don't know
[Developer]	4
[Developer]	Between 4-6
How would you rate competition in the supply of monopiles?	
[Foundation]	High
Designer / Survey	Don't know
[Developer]	Good
[Developer]	Limited with track record.
Do you see this improving over the next three years?	
[Foundation]	No

Designer / Survey	No
[Developer]	Yes
[Developer]	No
Do you expect to award contracts to any new or low cost entrants to the monopile supply market in the next few years? If so please provide details.	
[Foundation]	Possibly
Designer / Survey	N/A
[Developer]	No Known
How many suppliers of jackets would you consider are active in the market?	
[Foundation]	3
Designer / Survey	Don't know

[Developer]	6
[Developer]	6-10
How would you rate competition in the supply of jackets?	
[Foundation]	High
Designer / Survey	Don't know
[Developer]	High
[Developer]	Good with improving range of suppliers with experience.
Do you see this improving over the next three years?	
[Foundation]	Yes
Designer / Survey	No
[Developer]	No

[Developer]	Yes

47.3.2 Interview

Category	Interview response
[Developer]	In general [Developer] see a good level of competition in this market, accepting that the experience may be limited by the projects they have been exposed to.
[Foundation]	There is currently an oversupply for transition piece supply (capacity to produce 500 TPs per year in Europe). For monopiles there is more than enough capacity to meet the current and future demand. For jackets it is a bit tighter and in some years there will be a pinch point. In 2017/18 jacket orders will be significant and supply from outside Europe will take place. (Mediterranean, far east, middle East, china). Security of supply from capable suppliers could potentially be a risk for future projects using jackets. The amount of future projects happening in the market may force developers to look outside of northern Europe for supply of jacket fabrication.

47.3.3 Market intelligence

Evidence	Source

• EWEA's Annual market in 2015 report showed that foundations installed in 2015 were supplied by EEW (41.1%), Sif (34.1%), Bladt (21.6%), Smulders (3.8%), with decommissioning of AMEC foundations resulting in a decrease in market size by 0.6%.	http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2015.pdf
• In January 2016, Technip Offshore Finland announced that will manufacture the subsea foundations for the world's first offshore wind farm suitable for icy conditions, which will be built by Finish wind farm production company Suomen Hyötytuuli Oy. The construction of the offshore wind farm is scheduled to kick off this spring. The OWF will feature ten 4 MW offshore turbines, supplied by Siemens. The substation and main transformers are supplied by ABB. Technip will supply the gravity-based steel foundations caisson foundations, filled with rock material.	http://subseaworldnews.com/2016/01/27/technip-to-build-foundations-for-finland-offshore-wind-project/
• In October 2016, Seaway Heavy Lifting has awarded Bladt and BiFab contracts to fabricate 56 jacket foundations, while Dutch company Sif has won the contract to produce pin piles for the 588 MW Beatrice offshore wind farm off the coast of Scotland. Bladt will tackle 30 four-legged jackets which will be built at the company's Lindo yard in Denmark while BiFab will fabricate 26 foundations at using its facilities in Methil, Arnish and Burntisland.	http://renews.biz/103074/bladt-bifab-bag-beatrice-bounty/
• In June 2016, Fife-based BiFab has secured a £100 million contract to support the build-out of the massive Beatrice offshore wind farm in the Cromarty Firth. The work secured the work to build 26 subsea jackets for the project over the next two years. The company said the contract secured 200 jobs and would bring new work to all three of its facilities, including its Burntisland and Methil yards. Managing director John Robertson said the contract involved 22,500 tonnes of steel fabrication.	https://www.thecourier.co.uk/fp/business/business-news/190610/nigg-secures-beatrice-

	windfarm-construction-project/
• In August 2016, Bilfinger has sold its offshore wind manufacturing business to German industrial company VTC Group. VTC Group acquired Bilfinger's 62.5% interest in Bilfinger Mars Offshore, a joint venture that manufactures steel foundations for offshore wind turbines in the Polish city of Szczecin. Polish investment fund Mars will keep its 37.5% interest. Bilfinger put its offshore wind activities on sale last year and Dutch company Van Oord agreed to buy its offshore installation business last month. The selling process for the remaining marine construction activities will continue, according to the German engineering company. "In the course of our focus on the industrial sector, activities in the area of offshore wind energy are no longer part of our core business", Bilfinger chief financial officer Axel Salzmann said.	http://renews.biz/103694/bilfinger-sells-fabrication-business/
• In September 2016, Spanish firms Navantia and Windar have received €120m contract from Iberdrola to supply foundations for the 714 MW East Anglia One offshore wind farm in the North Sea. The £2.5bn project will feature 102 Siemens-built wind turbines to generate electricity required to power over 500,000 average UK households. Under the contract, Navantia will fabricate 34 jackets at its shipyard in Fene, Spain while Windar will build the jacket piles at its facilities in Avilés, Spain. Said to be one of the largest of its kind, the wind farm is planned to be fully-operational by 2020.	http://wind.energy-business-review.com/news/iberdrola-awards-foundations-contract-for-714mw-uk-offshore-wind-farm-080916-5000307
• UK based OGN group had hoped to be awarded the contract for supply foundations to the East Anglia One project and have criticised Scottish Power plans to procure the bulk of the fabrication work outside of the UK despite their previous promises of extensive UK content.	http://www.chronicleliive.co.uk/business/business-news/50m-scheme-would-

	created-1000-12015562

47.4 Additional comments

None for this indicator

47.5 Recommendations

None for this indicator

48Competition in HV topside equipment supply

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the industry	Electrical	Competition in HV topside equipment supply

48.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ in 2016 because evidence suggested reasonably healthy levels of competition in this area, with several fabricators from across Europe, including representatives from the UK actively engaged in the supply of HV topsides. There are at least 4 suppliers of electrical systems for HV topsides and at least as many fabricators delivering HV topsides.

Last year this indicator was also assessed as ‘on target’ noting that there was good competition in electrical equipment supply and even better competition between fabricators. CRMF 2015 also highlighted a dynamic which influences the actual level of competition which is that suppliers can sometimes generate an advantage in HV equipment supply by offering benefits across contract packages (e.g. turbines and HV electrical).

Outlook:

There remains a possibility of a non EU entrant into this market, which could influence the dynamics of competition, but the commitment of potential new market entrants remains uncertain.

A ‘high confidence’ outlook was expressed by industry, although the score only just exceeds that of ‘medium confidence’ reflecting the existence of some potential future challenges.

48.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>6 suppliers of HV topside fabrication and integration active in market	>6 suppliers of HV topside fabrication and integration active in market	>6 suppliers of HV topside fabrication and integration active in market	>6 suppliers of HV topside fabrication and integration active in market	>6 suppliers of HV topside fabrication and integration active in market
On target	4-5 suppliers of > HV Topside fabrication and integration active in market. Developer helping bring in new entrant	5-6 suppliers of HV topside fabrication and integration active in market	5-6 suppliers of HV topside fabrication and integration active in market	5-6 suppliers of HV topside fabrication and integration active in market	5-6 suppliers of HV topside fabrication and integration active in market
Behind target	2-3 suppliers of >120 kV HV topside fabrication and integration active in market	3-4 suppliers of >120 kV HV topside fabrication and integration equipment	3-4 suppliers of HV topside fabrication and integration cables active in market	3-4 suppliers of HV topside fabrication and integration cables active in market	3-4 suppliers of HV topside fabrication and integration cables active in market
Missed target	<2 suppliers of HV topside fabrication	<2 suppliers of HV topside fabrication	<2 suppliers of HV topside fabrication	<2 suppliers of HV topside fabrication	<2 suppliers of HV topside fabrication

	and integration active in market	and integration active in market	and integration active in market	and integration active in market	and integration active in market

48.3 Evidence

48.3.1 Questionnaires

Category	Questionnaire response
How many fabricators capable of supplying HV topsides do you think are active in the market?	
[Foundation]	6
Designer / Survey	Don't know
[Developer]	3 (Electrical equipment suppliers OEMs)
How would you rate competition in this market on the scale above?	
[Foundation]	High
Designer / Survey	Don't know

[Developer]	Poor
Do you see this improving over the next three years?	
[Foundation]	No
Designer / Survey	No
[Developer]	No

48.3.2 Interview

Category	Interview response
[Electrical]	Clients either ask for a turnkey solution, or as a purely electrical component/scope of supply. So they have seen completely different scopes. Projects are laced with risk when there is a fabricator in the mix.

	Small players struggle to make the grade through internal approvals process.

48.3.3 Market intelligence

Evidence	Source
• In October 2015, the Nobelwind team announced on a press conference that they have reached financial close on the Bligh Bank II offshore wind farm project, which allows Bladt to start the construction of the offshore high voltage substation. As the main contractor of the OHVS, Bladt Industries are responsible for the steel construction work of the substation as well as the overall engineering, procurement, construction and installation of the substation.	http://www.4coffshore.com/windfarms/nobelwind-offshore-substation-in-progress-nid2632.html
• In March 2016, STX France-Offshore Energy has signed a contract with Rentel N.V. for the engineering, supply and installation of the Offshore Substation destined for the Rentel offshore wind farm. After a competitive selection process, STX France has been awarded the order for the design, construction, installation and commissioning of the project's offshore substation which will be installed 32 km off the Belgian coast. Delivery is scheduled for 2018. This new order confirms STX France competitive position in the offshore wind market.	http://www.4coffshore.com/windfarms/stx-to-supply-rentel-substation-nid3425.html
• In March 2016, the FICG consortium of Cofely Fabricom, lemants and CG has been awarded a contract for the design, supply and installation of substation for the EnBW Hohe See offshore wind farm in the North Sea. Cofely	http://www.4coffshore.com/windfarms/ficg-consortium-to-supply-enbw-hohe-

Fabricom will carry out the Engineering Procurement Construction (EPC) and commissioning of the Offshore substation Jacket and Topside.	see-substation-nid3446.html
• In July 2016, offshore substation and all associated electrical components installed at the Nordsee One offshore wind farm. The topside was installed after it underwent a three-day journey from Aalborg, Denmark.	http://www.4coffshore.com/windfarms/nordsee-oss-installed-nid4174.htmlX187:AA187X187:Z187X187:Y187
• In August 2016, Iberdrola's Andalusia substation was installed at German Wikinger offshore wind farm. This electricity distribution infrastructure weighing about 8,500 tonnes is the energetic core of this renewable facility, which has a capacity of 350 MW and for which the overall budget is €1.4 billion.	https://www.iberdrola.com/press-room/news/detail/la-subestacion-andalucia-de-iberdrola-ya-esta-instalada-en-el-parque-eolico-marino-aleman-wikinger-1050338220160830

48.4 Additional comments

None for this indicator

48.5 Recommendations

None for this indicator

49 Competition in HV cable supply

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the industry	Electrical	Competition in HV cable supply

49.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	Ahead of target	↑	Medium confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because despite a merger between NKT and ABB there are still more than 5 suppliers capable of providing export cables for the offshore wind market.

It is interesting to note that developers also saw some competition in supply of 66 kV cables, with 3 – 4 suppliers considered capable of supply, with an expectation that the level of competition will increase in this area in future.

Last year this indicator was assessed as ‘on target’ noting that although there were a sufficient number of players to justify ‘ahead of target’ the competition, particularly at higher voltages and capacities was thought to be low.

Note that no companies from the cables supply chain were willing to contribute to this study, and as such evidence has been based on market intelligence and the experience of the customers of cable suppliers: Developers. Input was also gained from engagement with contractors in the installation and electrical areas.

Outlook:

It is likely that the current level of competition will continue in future years, and that the limited capability to supply higher voltage cables may continue to limit competition in that area. At present there is no UK export cable manufacturer, and it does not look likely that this situation will change before 2020 either. Cable suppliers may also supply other industries, which could mean that there will be less consolidation than in other offshore wind supply chain, although this remains to be seen.

A ‘medium confidence’ in the outlook for this indicator was expressed by industry, reflecting a moderate level of competition currently and a reluctance to expect competition to change significantly in coming years.

49.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>5 suppliers of >120 kV HVAC cables active in market. At least one new supplier of 66 kV cables enters the market.	>6 suppliers of >120 kV HVAC cables active in market. Evidence of competition starting to drive cost reduction in 66 kV cable supply.	>6 suppliers of >120 kV HVAC cables active in market. Evidence that competition in 66 kV cable supply has delivered cost reduction.	>6 suppliers of >120 kV HVAC cables active in market. Evidence that competition in 66 kV cable supply has delivered cost reduction.	>6 suppliers of >120 kV HVAC cables active in market. Evidence that competition in 66 kV cable supply has delivered cost reduction.
On target	4-5 suppliers of >120 kV HVAC cables active in	5-6 suppliers of >120 kV HVAC cables active in	5-6 suppliers of >120 kV HVAC cables active in	5-6 suppliers of >120 kV HVAC cables active in	5-6 suppliers of >120 kV HVAC cables active in

	market. Developers seeking to bring in new entrant. One new supplier of 66 kV cables enters the market.	market. Limited evidence of competition in 66 kV cable supply.	market. Evidence of competition starting to drive cost reduction in 66 kV cable supply.	market. Evidence of competition starting to drive cost reduction in 66 kV cable supply.	market. Evidence of competition starting to drive cost reduction in 66 kV cable supply.
Behind target	2-3 suppliers of >120 kV HVAC cables active in market. No new 66 kV suppliers.	3-4 suppliers of >120 kV HVAC cables active in market. No competition in 66 kV cable supply.	3-4 suppliers of >120 kV HVAC cables active in market. Limited evidence of competition in 66 kV cable supply.	3-4 suppliers of >120 kV HVAC cables active in market. Limited evidence of competition in 66 kV cable supply.	3-4 suppliers of >120 kV HVAC cables active in market. Limited evidence of competition in 66 kV cable supply.
Missed target	<2 suppliers of >120 kV HVAC cables active in market. No new 66 kV suppliers.	<2 suppliers of >120 kV HVAC cables active in market. No competition in 66 kV cable supply.	<2 suppliers of >120 kV HVAC cables active in market. No competition in 66 kV cable supply.	<2 suppliers of >120 kV HVAC cables active in market. No competition in 66 kV cable supply.	<2 suppliers of >120 kV HVAC cables active in market. No competition in 66 kV cable supply.

49.3 Evidence

49.3.1 Questionnaires

Category	Questionnaire response
How many suppliers of >120kV cables are active in the market?	

[Developer]	7 (NKT/ABB (merger), Prysmian, LS, Hellenic, Nexaas, J-Power, NSW)
How would you rate competition in this market on the scale above?	
[Developer]	Good
Do you see this improving over the next three years?	
[Developer]	Yes
How many suppliers of 66kV array cables are active in the market?	
[Developer]	3 possibly 4 (Prysmian (Draka), Hellenic, JDR, Nexans (possibly)
How would you rate competition in this market on the scale above?	
[Developer]	average
Do you see this improving over the next three years?	
[Developer]	No
[Developer]	Yes

49.3.2 Interview

Category	Interview response
None for this indicator	

49.3.3 Market intelligence

Evidence	Source
• 5 HV export suppliers are found to have been contracted for EU projects reaching FID in 2016: Prysmian, NKT Cables, ABB, NSW, Nexans.	4C Offshore
• On 11/02/16 According to "The European offshore wind industry – key trends and statistics 2015" report, in terms of export cables in 2015, 47 export cables manufactured by Prysmian were energised (44.7% of all export cables). Ten export cables manufactured by NKT (21.3%), along with seven from ABB (14.9%). Six from NSW (12.8%), and three from LS Cable & System (6.4%) completed the market in 2015.	http://www.offshorewind.biz/2016/02/11/2015-european-offshore-wind-in-numbers/
• In February 2016, Statoil has awarded Nexans the contract to supply static and dynamic cabling and associated accessories for the world's first floating wind farm, following a successful demo facilitated by Nexans' cables which has been in operation since 2009. Following the initial Norway demo, Statoil has awarded Nexans	http://www.offshorewindindustry.com/news/statoil-chooses-

a new contract worth approximately €10.2 million to service the Hywind Scotland Pilot Park wind farm. Nexans will deliver cables to the site, located 30 km off the coast of Aberdeenshire.	nexans-to-supply-cables
• In February 2016, the export cables that will flow power from Deepwater Wind's 30 MW Block Island offshore wind farm to US soil shipped out from South Korea to Rhode Island. The cables, manufactured by Korea's LS Cable & System, left Asia in mid-February aboard a transport vessel, and were due to arrive at Quonset Point, Rhode Island, by the end of March.	http://www.rechargenews.com/wind/1424953/block-islands-export-cables-ship-out-from-south-korea
• In March 2016, ABB has landed a $250m deal to supply a 220 kV export cable at Dong Energy's 1.2 GW Hornsea 1 offshore wind farm off the Yorkshire coast. The Swiss engineering giant will supply alternating current (AV) submarine cable systems for the project which will be some 120 km from shore. The cable will be fabricated by ABB at its Karlskrona facility in Sweden, it said today.	http://renews.biz/102112/abb-wins-hornsea-gem/
• In April 2016, Swedish company ABB AB has been awarded the contract for the export cable at the planned Belgian offshore wind farm Rentel. The contract is to design, produce and install the approximately 40km long cable which will connect the offshore substation to the onshore grid.	http://www.maritimejournal.com/news101/industry-news/export-cable-contract-for-offshore-wind-farm
• In April 2016, Dong has awarded a €139m contract to NKT for supply of 170 km of export cables for the 1.2 GW Hornsea 1 offshore wind farm in the UK. The manufacturer will provide 220 kV AC wires for one third of the export system, connecting the central circuit of the project with the mainland grid and to other circuits via two offshore interlinks. Hornsea will feature three phases -- east, centre and west -- with NKT supplying cable for one of those. ABB was announced as supplier for the other two last week. The wind farm electrical network is due to	http://renews.biz/102171/nkt-to-help-wire-hornsea-1/

be fully operational in 2019. NKT cables will be manufactured in Cologne, Germany, in 2017 and will be delivered for installation in early 2018.	
• In May 2016, Prysmian Group has announced the successful development and testing of its new 700 kV MI-PPL (Mass Impregnated) and 600 kV extruded (XLPE) cable systems for high voltage direct current (HVDC) applications. “It is the first time in the cable industry that voltages at these high levels have been achieved,” said Massimo Battaini, Senior Vice President Energy Projects at Prysmian Group. “These are also the first developments in cable technology that enable HVDC power transmission systems beyond 3 GW per cable bipole, and as such, are capable of more than double the power transmission capability of DC cable systems currently in service.” The voltage upgrades allow an increase in the power transmission capability by up to 15% beyond the previously highest voltage 525 kV XLPE technology and beyond that currently achieved with high performance PPL technology at voltage level of 600 kV, respectively. These milestone achievements follow Prysmian’s recent announcement of the successful testing of the 525 kV DC XLPE and 525 kV P-Laser cable solutions in December 2015 and March 2016, respectively.	http://www.offshorewind.biz/2016/05/24/prysmian-reaches-new-voltage-highs/

49.4 Additional comments

None for this indicator

49.5 Recommendations

None for this indicator

50 Competition in Turbine Installation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the industry	Installation	Competition in Turbine Installation

50.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there was evidence to suggest that there is strong competition in the market for wind turbine installation vessels even for the contemporary 6 – 8 MW class of turbines. Participants described a recent compression in day rates for installation vessels. There are comfortably more than 4 vessels capable of installing the largest turbines, although there may be a challenge for projects which require installation vessels capable of operating in deeper (>40 m) water.

Last year this indicator was also assessed as ‘ahead of target’ noting that there was also a trend for generally sufficient availability of turbine installation vessels, tending towards over supply.

The influence of a depressed oil and gas market may also be having an impact in this and other vessel related indicators by driving day rates and staff costs down compared to 2 – 3 years ago.

Outlook:

Perhaps not surprisingly there has not been much evidence of plans to design, order, or build new wind turbine installation vessels. It looks likely that until projects either predominantly move into significantly deeper water, and/or the class of turbines move again upwards in size (to something greater than 9-10 MW) that the capabilities of the existing wind turbine installation vessel fleet will prove sufficient and deliver adequate levels of competition in this market.

It will be worth considering the potential in future for markets outside of northern Europe to start to have an influence on the availability of specialist wind turbine installation vessels, which are anticipated to be in demand as projects in new regions start to be deployed.

A 'high confidence' was expressed by industry in the outlook for this indicator, participants generally felt that for the foreseeable future there would be strong levels of competition in the wind turbine installation market.

50.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>15 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	>20 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.	>20 WTIVs active in European market. At least 6 vessels capable of installing 6 – 8 MW turbines.	>20 WTIVs active in European market. At least 7 vessels capable of installing 6 – 8 MW turbines.	>20 WTIVs active in European market. More than 10 vessels capable of installing 6 – 8 MW turbines.
On target	10-15 WTIVs active in European market. Another 3-5 vessels are under construction At least 3 vessels	15-20 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	15-20 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.	15-20 WTIVs active in European market. At least 6 vessels capable of installing 6 – 8 MW turbines.	15-20 WTIVs active in European market. At least 7 vessels capable of installing 6 – 8 MW turbines.

	capable of installing 6 – 8 MW turbines.				
Behind target	5-9 WTIVs active in European market. At least 2 vessels capable of installing 6 – 8 MW turbines.	10-14 WTIVs active in European market. At least 3 vessels capable of installing 6 – 8 MW turbines.	10-14 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	10-14 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.	10-14 WTIVs active in European market. At least 6 vessels capable of installing 6 – 8 MW turbines.
Missed target	<5 WTIVs active in European market	<10 WTIVs active in European market. At least 2 vessels capable of installing 6 – 8 MW turbines.	<10 WTIVs active in European market. At least 3 vessels capable of installing 6 – 8 MW turbines.	<10 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	<10 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.

50.3 Evidence

50.3.1 Questionnaires

Category	Questionnaire response
How many proven turbine installation vessels would you consider active in the market?	
[WTG OEM]	10
[Installation]	13

[WTG OEM]	More than 8 installation vessels
[Developer]	Circa 15 vessels
[Developer]	About 9 for water depths of 40-45 m, not all of them necessarily optimum.
How would you rate competition in turbine installation vessel supply?	
[WTG OEM]	Good, although it again depends on the project. For deeper water projects, the number of relevant installation vessels quickly decreases
[Installation]	WTG installation market still has an oversupply of vessels leading to increased competition.
[WTG OEM]	Adequate - reduced aspirations means vessel market is coping with current demand levels.
[WTG OEM]	Confidentiality considerations
[WTG OEM]	Don´t know

[Developer]	Good
[Developer]	(scale not visible, probably a 7/10)
Do you see this improving over the next three years?	
[WTG OEM]	Yes
[Installation]	No
[WTG OEM]	No
[WTG OEM]	Yes
[Developer]	No
[Developer]	No
Does the level of competition change significantly when planning for the installation of 6 - 8MW turbines? If so please provide details.	

[WTG OEM]	No. Response as above
[Installation]	There are a number of vessels capable of installing WTG in this range. The most significant variable is the project location and weather which will restrict some of the vessels.
[WTG OEM]	All major suppliers have capability in this range so still 3-4 competitors available
[WTG OEM]	At present [PRODUCT] 8 MW is the most competitive turbine in the offshore market as its advantages, regarding to 6 MW WTG, are well- know. For example, [PRODUCT], with a 180 m diameter, has the highest Annual Energy Production in the industry, thus, it contributes to reduce the LCOE, as well as, savings from BOP.
[Developer]	Not significant. Possibly means more installation cycles are required
[Developer]	Not much in capability but yes for efficiency.

50.3.2 Interview

Category	Interview response

How would you rate competition?	
[Installation]	There is likely to be a slight oversupply of vessels between now and 2020 for the current generation of turbines, which may have cost reduction benefits for now but could have adverse cost impacts in the future.
[Installation]	From the perspective of [Installation], the best way to reduce the day rate of vessels is to have half the vessels in the market that are capable of doing a project fully utilised than all of them half utilised when it comes to day rates and overall cost reduction. Therefore it is slightly unhealthy that we have a current over capacity of vessels because some of the vessel owners (not [Installation]) can afford to play the waiting game and provide high rates to developers who are late to secure vessels. Therefore some developers are getting good rates and some are not.
[Installation]	Regards a step change or restriction in market availability of turbine installation vessels, this is not really required until there is a step change. For example if [WTG OEM] were to progress with a D1.X turbine then there are probably no vessels (some people may say maybe Scyla could) available to install another step change upwards in turbine size. At the moment turbine OEMs are engaging with the vessel market now to ask around for what vessels may be able to install a next generation turbine so that they have some understanding of the constraints and what vessels are out there should they go ahead and develop a next gen turbine platform
[Installation]	Whilst there may be generally strong competition resulting from slight oversupply, the level of competition in installation vessels is somewhat influenced by how contracting is structured, for example see a difference in motivations and levels of competition between those who contract directly with vessel owners or those who for example take an EPCI approach.
Do you see this improving over the next three years?	

[WTG OEM]	Vessel providers are thinking ahead and are being seen to extend legs and capabilities of installation vessels. Vessel operators are maybe not quite so enthusiastic about how to reduce costs overall, [WTG OEM] feel that they really are living and breathing the effort required to get cost out of projects, but that in general vessel market is less determined to see this and are more business-like/prepared to push prices up and make good money any time that there may be a scarcity. Not expecting to see installation of turbines from a floating vessel.
[Installation]	The problem with all of these things is pipeline. So from a vessel owners point of view (in a similar way to a turbine OEM) development and construction costs of new vessels do not currently look economical as there is little certainty of what the pipeline of work could be.
[Installation]	The cost of electricity is coming down massively, this is being driven by efficiencies, but also by hardening up of vessel day rates. For example, if a vessel was forecast when built to achieve a day rate of ~$200,000/day, but after it has been built, and in current market conditions only achieves $150,000/day then the business case for the investment in what may be a $200m vessel could look very different. Vessel day rates have been coming down for the last year or more. This is a simple example of supply and demand. There is an expectation that looking forward there may be a tiered market in installation: premier league, championship and first division, and that as more projects line up and either have requirements or expectations that they need the biggest/most capable vessels the effects of supply and demand will come back in. Also important not to lose sight of the difference between what is a vessel capability on paper and what is actually delivered on projects in terms of installation time for example which continues to improve/reduce.

	Installation time, has seen foundation or turbine installations come down from previously estimated 24 hours/one per day coming down now to about 16 or 18 hours, so there has been an improvement here, whilst at the same time remaining sensitive to weather.
Does the level of competition change significantly when planning for the installation of 6 - 8MW turbines? If so please provide details.	
[Installation]	The current oversupply of vessels means that until there is some firm commitment from OEMs to begin selling 10MW+ turbines, vessel owners will be hesitant to pull the trigger on investment in next generation vessels without a clear order book. This may mean that there isn't the required investment going into the development of next generation vessels to meet future demand, which may increase day rates for vessels in the future.
[Installation]	Upgrade of existing vessels can be a costly business, with competitors describing spends of tens of millions of dollars invested to keep relatively new jack up vessels relevant.

50.3.3 Market intelligence

Evidence	Source
• In May 2016, A2SEA's SEA CHALLENGER completed the installation of 97 Siemens 6 MW turbines at DONG Energy's Gode Wind 2+1 OWF in the German part of the North Sea.	https://www.vesselfinder.com/news/6180-A2SEAs-Sea-Challenger-completes-Turbine-Installation-At-

	GODE-WIND-2--1-Offshore-Wind-Farm
• In May 2016, the MPI Discovery wind farm installation vessel, owned by MPI Offshore was undergoing repairs in A&P Group's Tyne yard. It is one of the world's most advanced and efficient wind turbine installation vessels.	http://www.ship-technology.com/projects/mpi-discovery-wind-turbine-installation-vessel/
• On 29/06/16 MHI Vestas have been asked to deliver five of the largest wind turbines ever manufactured in the world (V164-8.0 MW) turbines, and these will be installed using the by Jan De Nul Group Installation Vessel. The vessel Vole au vent will be mobilized to execute the turbine installation. “Jan De Nul is one of the first to install this new mega turbine and is of course very proud to be a part of this innovative demonstrator project and to work for one of the most important players in the market,” explains Peter De Pooter, Area Manager Renewables at Jan De Nul Group.	http://www.jandenul.com/en/pressroom/press-releases/jan-de-nul-group-to-supply-installation-vessel-to-install-turbines-for
• In July 2016, Japan’s Penta-Ocean Construction and Japan Marine United Corporation (JMU) have signed a contract for the construction of one multi-purpose self-elevating platform vessel suitable for marine civil engineering works or offshore wind turbine installation in harsher weather and marine conditions. The basic design of the jack-up vessel, the first of its kind to be built in Japan, has been supervised by the Netherlands-based GustoMSC. The vessel is designed based on jack-ups used in Europe for installation of oil rigs or offshore wind turbines, but with a jack-up system that matches Japanese natural conditions and on-site characteristics.	http://www.offshorewind.biz/2016/07/27/penta-ocean-orders-first-japanese-built-wind-turbine-installation-vessel/

• In the same month, MPI Offshore announced that their wind turbine installation vessel MPI Adventure installed the first of 72 SWT-4.0-130 offshore wind turbines on the Sandbank offshore wind farm. MPI Adventure is capable of installing 6 of these complete offshore wind turbines per cycle.	http://www.mpi-offshore.com/2016/07/mpi-adventure-installs-first-offshore-wind-turbine-sandbank/
• On 16th August 2016, Senvion installed the rotor star on the first of eighteen 6.2M126 turbines at the Nordergründe offshore wind farm. By Tuesday, the installation vessel MPI Enterprise was already on its way to the site of the second turbine, the erection of which will complete the initial phase of installations. The MPI Enterprise will then return to the CT1 base port (Eurogate container terminal) in Bremerhaven for the second phase and installation of the next two turbines. The project is being erected and managed by the wpd Group within the 12-nautical-mile zone approximately 40 kilometers northwest of Bremerhaven.	https://www.senvion.com/global/en/company/news-stories/detail/first-turbine-installed-at-nordergruende-offshore-wind-farm/
• On 24th August 2016, Van Oord's offshore installation vessel Aeolus installed the final wind turbine at the Gemini Offshore Wind Park, which means that the installation of all 150 wind turbines is now complete.	http://www.vanoord.com/news/2016-van-oord-completes-installation-gemini-offshore-wind-park
• In September 2016, A2SEA's turbine installation vessel Sea Installer has installed the first MHI Vestas V164-8 MW turbine – the largest wind turbine installed on an offshore windfarm to date – on the Burbo Bank Extension offshore windfarm. The first turbine out of a total of 32 to be installed at Burbo Bank Extension was installed on 8 September. Over the next few months Sea Installer will install the remainder of the turbines, which are being shipped from Belfast. Sea Installer is able to carry four 8 MW turbines at a time.	http://www.owjonline.com/news/view,first-mhi-vestas-8mw-turbine-installed_44712.htm

• In October 2016, EU-backed €3.6m Elisa research project developed a wind turbine system that can be completely pre-assembled in controlled harbour conditions. According to the research team, the system was developed to tackle the high costs of installing turbines, which is seen as one of the main barriers to widespread roll-out of offshore wind farms. José Serna, research project engineer in the project said that "it's important to note that currently there are only three or four heavy-lift vessels in Europe capable of installing an 8 MW turbine in waters deeper than 40 m - and Europe leads the way in comparison to other developed markets," adding that the system could be a key EU export to the fledgling US and Japanese offshore wind markets.	http://www.businessgreen.com/bg/news/2474549/researchers-develop-self-installing-offshore-wind-turbine

50.3.4 Turbine installation vessels

This table lists vessels active or capable of competing in the turbine installation market. The listed project experience has not been limited to turbine installation because several vessels have been used for both turbine and foundation installation. Some jack up barges (un-propelled) have been used for turbine installation in the past but have not been included in the table because they have limited relevance to the current or future turbine installation market.

Vessel Type	Company	Vessel Name	Crane max	Working depth / leg length (m)	Windfarm Experience	Year built
Jack up vessel (self-propelled)	SeaJacks	Seajacks Scylla	1,500 t	65 / 105	Veja Mate foundations (2016) Scheduled for Walney Extension (2017)	2015

Jack up vessel (self-propelled)	DEME/ Geosea	Innovation	1,500 t	xx / 89	Race bank foundations (2016), Global Tech I, Westernmost Rough (2014), Gode Wind 1 & 2 (2015) - foundations, West of Duddon Sands, Westernmost Rough,	2012
Jack up vessel (self-propelled)	Swire Blue Ocean	Pacific Orca	1,200 t	65 / 105	Rampion (2016) West of Duddon Sands, (2013), Borkum Riffgrund 1 (2014) - foundations Sandbank	2012
Jack up vessel (self-propelled)	Swire Blue Ocean	Pacific Osprey	1,200 t	65 / 105	Gemini (2016), Belwind Haliade Demo (2013) - foundations, Dan	2012

					Tysk (2014) - Turbines Horns Rev , Gemini, Burbo Bank, Rhyl Flats, Walney I & II	
Jack up vessel (self-propelled)	Workfox BV	Seafox 5	1,200 t	65 / xx	Dan Tysk (2013 F)	2012
Jack up vessel (self-propelled)	Jan De Nuul	Vole Au Vent	1,200 t	50 / 90	Global Tech 1, EnBW Baltic 2, Scheduled for Nobelwind (2016/17 Foundations and turbines), Borkum Riffgrund foundations (2018),	2013
Jack up vessel (self-propelled)	MPI	MPI Adventure	1,000 t	40 / xx	London Array Phase 1 (2011 - Foundations), Teesside (2012), Humber	2011

					Gateway, Borkum Phase 1, Amrumbank West (2015), Sandbank (2015, 2016)	
Jack up vessel (self-propelled)	MPI	MPI Discovery	1,000 t	40 / xx	Rampion (2016), London Array Phase 1 (2011), Lincs (2012), Amrumbank West (2013 - Foundations), Karehamn (2013), Humber Gateway (2013/14 F & T)	2011
Jack up vessel (self-propelled)	Van Oord	Aeolus	990 t	55 / 81	Eneco Luchterdein (2015 - F & T), Gemini (2015 - F & T)	2014

Jack up vessel (self-propelled)	A2SEA	Sea Challenger	900 t	60 / 82	Gode Wind 1 & 2, Anholt, Burbo Bank, Greater Gabbard, Westernmost Rough (2014). Contracted for Burbo Bank Extension in 2016 and Race Bank in 2017	2013
Jack up vessel (self-propelled)	A2SEA	Sea Installer	900 t	60 / 82	Anholt (2012), WoDS (2013), Gunfleet Sands 3 Demo (2013), Borkum Riffgrund (2014), Meerwind Ost/Sud, Walney Phase 2, WoDS (2014), Gode Wind 1 & 2 (2015), Dudgeon (2016/2017)	2012

Jack up vessel (self-propelled)	MPI	MPI Enterprise	800 t	45 / xx	Amrumbank West (2015) , Nordsee Ost (2012)	2011
Jack up vessel (self-propelled)	SeaJacks	Seajacks Zaratan	800 t		Meerwind Ost/Sud (2013 - F & T), Gunfleet Sands	2012
Jack up vessel (self-propelled)	Fred Olsen	Bold Tern	800 t	78 / 45	Belwind Alstom Demonstration (2013), Riffgat (2013), Global Tech I (2014), Butendiek (2014/15)	2012
Jack up vessel (self-propelled)	Fred Olsen	Brave Tern	800 t	78 / 45	Block Island (2016), Bard (2013), Global Tech I (2014)	2011

Jack up vessel (self-propelled)	DEME / Geosea	Apollo	800 t	70 / 84 (extendable to 106)		2017
Jack up vessel (self-propelled)	DEME / Geosea	Neptune	600 t	Xx / 80 (extendable to 92)	Thornton Bank Phase 3 (2013), Northwind (2013- T & F), Trianel Borkum Phase 1(2013), EnBW Baltic 2 (2014), Kentish Flats Extension (2015 - T & F)	2012
Jack up vessel (self-propelled)	MPI	MPI Resolution	600 t	35 / xx	Lincs (2011/12 - F & T), Humber Gateway (2013 - Foundations)	2004
Jack up vessel (self-propelled)	Otto Wulf Gmbh	Wind Lift 1	500 t	45 / 71	Bard (2013)	2010

Semi-jack up vessel (self-propelled)	OIS international	Excel	450 t	24 / xx	Arkona, Samso, Horns Rev 1, Nysted, Horns Rev 2, Rodsand 2, Sprogo, Arklow Bank, Prinsses Amalia, Egmond aan Zee, Utgrunden, Lillgrund, Gunfleet sands, Kentich flats, Robin Rigg, Scroby sands	1990
Jack up vessel (self-propelled)	DEME/ Geosea	Goliath	400 t	xx / 78.8	Thornton Bank Phase 3 (2013) - Turbines Walney Phase 1 (2010) - Foundations	2009
Jack up vessel (self-propelled)	SeaJacks	Seajacks Leviathan	400 t	41 / xx	Greater Gabbard (2010), Sheringham Shoal (2011),	2009

					Walney Phase 2(2011), Meerwind Ost/Sud (2013), Humber Gateway	
Jack up vessel (self-propelled)	SeaJacks	Seajacks Hydra	400 t	48 / xx	Global Tech 1	2014
Jack up vessel (self-propelled)	SeaJacks	Seajacks Kraken	300 t		Greater Gabbard (2010), Walney Phase 1 (2010), Walney Phase 2 (2011)	2009
Jack up vessel (self-propelled)	Gulf Marine	GMS Endeavour	300 t	65 / 94	Sheringham Shoal (2011)	2010

50.4 Additional comments

None for this indicator

50.5 Recommendations

None for this indicator

51 Competition in Foundation Installation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the market	Installation	Competition in Foundation Installation

51.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ in 2016 because although there is no evidence of orders being placed for new foundation installation vessels engagement suggested generally healthy levels of competition, tempered by the availability of vessels able to operate in deeper waters.

Last year this indicator was also assessed as on target noting that generally the level of competition was ‘ahead of target’ in the smaller, lower capacity WTIV end of the market but ‘behind target’ in larger HLV giving an average of ‘on target’. Evidence suggested that wind turbine foundations have been installed by floating heavy lift vessels or barges, and by jack up vessels. At the upper end of the lifting capacity scale HLV used for turbine foundation (jacket or monopile) installation have also been used for offshore substation foundation and topside installation. There is limited evidence of floating heavy lift vessels being used to install turbines (excepting the Beatrice demonstrator and some non-EU demonstrator projects). At the lower end of the lifting capacity scale several jack up WTIV have been used for both foundation and turbine installation.

Since there has been the addition of only the Scylla, which has found work deploying XXL monopiles for the Veja Mate project, the situation remains largely unchanged from previous years.

Outlook:

The placing of orders for new foundation installation vessels at present looks unlikely. Although the level of competition, particularly for foundations over 1000 t is less than in lower weight operations or turbine installation it looks unlikely that any project will not be able to secure a capable installation vessel in the near future. As noted in previous years, every project may not be able to select the installation vessel which it would consider ideal for their requirements, because the demands of individual projects and capabilities of vessels as well as their availability all vary and the pool of vessels in the market is relatively small. However it is expected that in at least the next few years strong competition in foundation will continue.

The requirement for a larger number of vessels to drive competition was defined by CRP when the pipeline of projects was greater, as such it is expected that the current number of vessels competing for the relatively small installation pipeline will maintain competition in the years to the end of the decade. Further there is a trend for installation contractors to operate in partnerships, particularly the main European dredging conglomerates, and there remains the possibility of further consolidations in the installation market in future.

Several novel concepts exist in turbine/foundation/vessel design, but there is no evidence to suggest that any of these more radical installation techniques will see development or demonstration by 2020.

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, suggesting that on balance most felt that a good level of competition was likely to continue in the coming years.

51.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020

Ahead of target	>10 HLVs active in European market >15 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	>15 HLVs active in European market >20 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.	>15 HLVs active in European market >20 WTIVs active in European market. At least 6 vessels capable of installing 6 – 8 MW turbines.	>15 HLVs active in European market >20 WTIVs active in European market. At least 7 vessels capable of installing 6 – 8 MW turbines.	>15 HLVs active in European market >20 WTIVs active in European market. At least 10 vessels capable of installing 6 – 8 MW turbines.
On target	7-10 HLVs active in European market 10-15 WTIVs active in European market. 3-5 new HLV are ordered and 3-5 WTIV. At least 3 vessels capable of installing 6 – 8 MW turbines.	12-15 HLVs active in European market 15-20 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	12-15 HLVs active in European market 15-20 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.	12-15 HLVs active in European market 15-20 WTIVs active in European market. At least 6 vessels capable of installing 6 – 8 MW turbines.	12-15 HLVs active in European market 15-20 WTIVs active in European market. At least 7 vessels capable of installing 6 – 8 MW turbines.
Behind target	4-6 HLVs active in European market 5-9 WTIVs active in European market. At least 2 vessels capable of installing 6 – 8 MW turbines.	7-11 HLVs active in European market 10-14 WTIVs active in European market. At least 3 vessels capable of installing 6 – 8 MW turbines.	7-11 HLVs active in European market 10-14 WTIVs active in European market. At least 4 vessels capable of installing 6 – 8 MW turbines.	7-11 HLVs active in European market 10-14 WTIVs active in European market. At least 5 vessels capable of installing 6 – 8 MW turbines.	7-11 HLVs active in European market 10-14 WTIVs active in European market. At least 6 vessels capable of installing 6 – 8 MW turbines.
Missed target	<4 HLVs active in European market <5 WTIVs active in European market. 2 or fewer vessels capable of installing 6 – 8 MW turbines.	<7 HLVs active in European market <10 WTIVs active in European market. 3 or fewer vessels capable of installing 6 – 8 MW turbines.	<7 HLVs active in European market <10 WTIVs active in European market. 4 or fewer vessels capable of installing 6 – 8 MW turbines.	<7 HLVs active in European market <10 WTIVs active in European market. 5 or fewer vessels capable of installing 6 – 8 MW turbines.	<7 HLVs active in European market <10 WTIVs active in European market. 6 or fewer vessels capable of installing 6 – 8 MW turbines.

51.3 Evidence

51.3.1 Questionnaires

Category	Questionnaire response
How many proven foundation installation vessels would you consider active in the market?	
[Foundation]	10
Designer / Survey	At least 10
[Developer]	13-15
[Developer]	It depends largely on the foundations, probably more than 10, but with competition between different offshore wind activities (mainly WTGs). The number might change with some traditional O&G options coming to offshore wind.
How would you rate competition?	
[Foundation]	High

Designer / Survey	There must be quite strong competition given the current pipeline of projects.
[Developer]	good
[Developer]	(Scale not visible 7/10)
Do you see this improving over the next three years?	
[Foundation]	No
Designer / Survey	Yes
[Developer]	Yes
[Developer]	Yes
Does the level of competition change significantly when considering the installation of the next generation (larger/deeper water) of offshore wind foundations? If so please provide details.	
[Foundation]	Yes: few vessels have lifting capacities above 1000 tons.

Designer / Survey	Likely this will go to more floating installation vessels but these are available in the O&G market I would think.
[Developer]	Yes, fewer capable vessels, even fewer suction based experience.
[Developer]	Yes, larger foundations are suitable for less vessels.

51.3.2 Interview

Category	Interview response
[Installation]	The same is also probably true for vessels to install jackets [as for WTIV], the tools to lift, in particular hook height could present a challenge for the current fleet of vessels. There may at the moment only be 2 or 3 vessels capable of installing jackets. How to store, prep and move jackets onshore and in port, particularly at scale and industrial volumes is also challenging.
[Installation]	Upgrade of existing vessels can be a costly business, with competitors describing spends of tens of millions of dollars invested to keep relatively new jack up vessels relevant.
[Installation]	The cost of electricity is coming down massively, this is being driven by efficiencies, but also by hardening up of vessel day rates. For example, if a vessel was forecast when built to achieve a day rate of ~$200,000/day, but after it has been built,

	and in current market conditions only achieves $150,000/day then the business case for the investment in what may be a $200m vessel could look very different. Vessel day rates have been coming down for the last year or more. This is a simple example of supply and demand. There is an expectation that looking forward there may be a tiered market in installation: premier league, championship and first division, and that as more projects line up and either have requirements or expectations that they need the biggest/most capable vessels the effects of supply and demand will come back in. Also important not to lose sight of the difference between what is a vessel capability on paper and what is actually delivered on projects in terms of installation time for example which continues to improve/reduce. Installation time, has seen foundation or turbine installations come down from previously estimated 24 hours/one per day coming down now to about 16 or 18 hours, so there has been an improvement here, whilst at the same time remaining sensitive to weather.
[Installation]	Whilst there may be generally strong competition resulting from slight oversupply, the level of competition in installation vessels is somewhat influenced by how contracting is structured, for example see a difference in motivations and levels of competition between those who contract directly with vessel owners or those who for example take an EPCI approach.
[Foundation]	The market appears to be consolidating to 4 large marine contractors for foundation installation. These big players are looking at larger vessels for foundation installation, depending on the appetite and pipeline for larger foundations. Despite this there is currently enough vessel capacity to install the current generation of foundations in the European market.

51.3.3 Market intelligence

Evidence	Source
• The assets and activities of Ballast Nedham offshore have been acquired by Van Oord.	http://www.vanoord.com/news/2014-van-oord-will-acquire-activities-ballast-nedam-offshore
• In April 2016, energy supplier E.ON has awarded the contract for the transport and installation of foundations at the Arkona offshore wind project in the German Baltic Sea to Van Oord. Van Oord will install the project's 60 monopiles and transition piece foundations. For installing foundations at the Arkona offshore wind project, Van Oord intends to deploy its heavy lift installation vessel Svanen. The Svanen has already installed over 500 monopiles using this method. The installation works are planned for 2017.	http://subseaworldnews.com/2016/04/25/van-oord-to-install-arkona-foundations/
Monopiles for the 8 MW MHI Vestas turbines at Burbo bank extension were installed by the Van Oord vessel Svanen.	http://www.burbobankextension.co.uk/en/news/articles/installation-of-foundations-completed-at-dong-energy%E2%80%99s-burbo-bank-extension-offshore-wind-farm

1300 t monopiles for the Veja Mate project in Germany were installed by the Seajacks vessel Skyla, the largest jack up wind farm installation vessel in the world.	http://www.volker-stevin.com/en/about-us/news/detail/24-xxl-monopiles-installed-for-veja-mate-project
• In July 2016, MPI Offshore said its turbine installation vessel MPI Discovery has recommenced work at the Rampion offshore windfarm off the south coast of the UK. Working closely together with Swire Blue Ocean's Pacific Orca, MPI Discovery will continue with the installation of 116 monopile foundations during the second half of 2016. As a result of the black bream spawning season, installation activity was halted in late April as planned and only restarted at the beginning of July. This break in activity provided MPI Offshore with the opportunity to complete a dry-docking of MPI Discovery. In the same period, the second installation vessel, Pacific Orca, was mobilised to join the foundation installation campaign.	http://www.owjonline.com/news/view,mpi-discovery-recommences-rampion-foundation-installation-campaign_43667.htm
• In August 2016, the Hamburg based engineering & design company HeavyLift@Sea presented the advanced Floating Foundation installation vessel concept FFI 1700 suitable for deep water installation of large monopiles, jackets and tripods.	http://www.4coffshore.com/windfarms/heavylift@sea-present-new-vessel--floating-foundation-installation-vessel-ffi-1700-nid4413.html
• Huisman has secured new crane contracts with a total value of around €300 million ($338 million) from various contractors, including two 900 tonne capacity heavy lift ship cranes for BigLift Shipping. The two cranes for BigLift are destined for installation on the company's third Happy S-type newbuild vessel, Happy Sun, which is	http://www.heavyliftpfi.com/news/huisman-

scheduled for delivery in the first quarter of 2018. The cranes will be built at Huisman's production facilities in the Netherlands, Czech Republic and China.	wins-heavy-lift-orders.html
• SAL Heavy Lift signs a major contract with Van Oord for a long term engagement at the Walney Offshore Wind Project. MV “Svenja” is chartered for 30 voyages for transportation of 87 monopiles from Rostock (D) to Belfast, 47 transition pieces from Aalborg (DK) and 40 from Teesside (UK) to Belfast (UK). In total an amount of 87 monopiles with diameter up to 8.40 m and weight up to 970 tons per monopile as well as 87 transition pieces will be transported. The transition pieces are measuring up to 30 m with up to 7 m diameter and are weighing up to 579 tons. This is the second major contract, SAL signed for Offshore support in 2016. With its vessel MV “Trina” SAL has just finalized the Veja Mate Offshore Wind Farm project, transporting in total 68 transition pieces in eleven consecutive voyages from Aalborg to Eemshaven.	http://www.hellenicshippingnews.com/sal-heavy-lift-signs-long-term-contract-for-walney-offshore-wind-project/

51.4 Foundation installation vessels

This table lists vessels active or capable of competing in the foundation installation market. The listed wind farm experience is not limited to foundation installation and several vessels have been used for both turbine and foundation installation. Some vessels have also been used for substation foundation and topside installation. Some jack up barges (un-propelled) have been used for foundation installation in the past but are thought to have limited relevance to current or future foundation installation market.

Vessel Type	Company	Vessel Name	Crane max	Working depth / leg length (m)	Wind farm Experience	Year built
Heavy Lift Vessel (self-Propelled)	Van Oord	Svanen	8,200 t	n/a	Burbo bank extension (2016), Sheringham	1991

	(acquired vessel in 2015 from Ballast Nedam)				Shoal (2010), Anholt (2011), London Array Phase 1 (2011), Walney Phase 2 (2011), Amrumbank West (2013), EnBW Baltic 2 (2013), Belwind (2010), Gunfleet Sands, Butendiek (2014), Westermeerwind (2015). Planned for Burbo Bank Extension foundations (2016). Scheduled for Arkona	
Heavy Lift Vessel (self-propelled)	DEME (Scaldis)	Gulliver	4,000 t	n/a	not yet on market - under construction	2017 (expected)

Heavy Lift Barge (un propelled)	DEME (Scaldis)	Rambiz 3000	3,300 t	n/a	Thornton Bank Phase 1, 2 & 3, Borkum Riffgrund, Amrumbank West, Nordsee Ost, Butendiek, Baltic 2, Nysted, Rodsand, Gemini, Luchterduinen, London Array, Walney 1 & 2, West of Duddon Sands, Beatrice Demonstrator.	1976
Heavy Lift Vessel (self-propelled)	Seaway Heavy Lifting	Oleg Strashnov	5,000 t	n/a	Dudgeon (2016), Sheringham Shoal (2010) Trianel Borkum Phase 1 (2011), Riffgat (2012), Dan Tysk, Meerwind Ost/Sud, Borkum	2011

					Phase 1, Greater Gabbard, Walney Extension.	
Heavy Lift Vessel (self-propelled)	Seaway Heavy lifting	Stanislav Yudin	2,500 t	n/a	Global Tech 1, Sandbank 2016), Borkum Phase1, Baltic 2, Anholt, Greater Gabbard, Gwnt y Mor, Westernmost Rough,	1985
Heavy Lift Vessel (Self Propelled) Floating sheerleg crane	SMIT	Taklift 4	2,200 t	n/a	Belwind, Alpha Ventus, Wikinger, Baltic 2	1981
Jack up vessel (self-propelled)	SeaJacks	Seajacks Scylla	1,500 t	65 / 105	Veja Mate (2016 F) and Walney Extension (2017 T)	2015

Jack up vessel (self-propelled)	DEME/ Geosea	Innovation	1,500 t	xx / 89	Global Tech I, Westernmost Rough (2014), Gode Wind 1 & 2 (2015) - foundations, West of Duddon Sands, Westernmost Rough,	2012
Jack up vessel (self-propelled)	Swire Blue Ocean	Pacific Orca	1,200 t	65 / 105	Rampion (2016) West of Duddon Sands, (2013), Borkum Riffgrund 1 (2014) - foundations Sandbank	2012
Jack up vessel (self-propelled)	Swire Blue Ocean	Pacific Osprey	1,200 t	65 / 105	Gemini (2016), Belwind Haliade Demo (2013) - foundations, Dan Tysk (2014) - Turbines Horns Rev , Gemini,	2012

					Burbo Bank, Rhyl Flats, Walney I & II	
Jack up vessel (self-propelled)	Workfox BV	Seafox 5	1,200 t	65 / xx	Dan Tysk (2013 F)	2012
Jack up vessel (self-propelled)	Jan De Nuul	Vole Au Vent	1,200 t	50 / 90	Global Tech 1, EnBW Baltic 2, Scheduled for Nobelwind (2016/17 Foundations and turbines), Borkum Riffgrund foundations (2018),	2013
Jack up vessel (self-propelled)	MPI	MPI Adventure	1,000 t	40 / xx	London Array Phase 1 (2011 - Foundations), Teesside (2012), Humber Gateway, Borkum Phase 1, Amrumbank	2011

					West (2015), Sandbank (2015, 2016)	
Jack up vessel (self-propelled)	MPI	MPI Discovery	1,000 t	40 / xx	Rampion (2016), London Array Phase 1 (2011), Lincs (2012), Amrumbank West (2013 - Foundations), Karehamn (2013), Humber Gateway (2013/14 F & T)	2011
Jack up vessel (self-propelled)	Van Oord	Aeolus	990 t	55 / 81	Eneco Luchterdein (2015 - F & T), Gemini (2015 - F & T)	2014
Jack up vessel (self-propelled)	A2SEA	Sea Challenger	900 t	60 / 82	Gode Wind 1 & 2, Anholt, Burbo Bank, Greater Gabbard,	2013

					Westernmost Rough (2014). Contracted for Burbo Bank Extension in 2016 and Race Bank in 2017	
Jack up vessel (self-propelled)	A2SEA	Sea Installer	900 t	60 / 82	Anholt (2012), WoDS (2013), Gunfleet Sands 3 Demo (2013), Borkum Riffgrund (2014), Meerwind Ost/Sud, Walney Phase 2, WoDS (2014), Gode Wind 1 & 2 (2015), Dudgeon (2016/2017)	2012
Jack up vessel (self-propelled)	MPI	MPI Enterprise	800 t	45 / xx	Amrumbank West (2015) , Nordsee Ost (2012)	2011

Jack up vessel (self-propelled)	SeaJacks	Seajacks Zaratan	800 t		Meerwind Ost/Sud (2013 - F & T), Gunfleet Sands	2012
Jack up vessel (self-propelled)	Fred Olsen	Bold Tern	800 t	78 / 45	Belwind Alstom Demonstration (2013), Riffgat (2013), Global Tech I (2014), Butendiek (2014/15)	2012
Jack up vessel (self-propelled)	Fred Olsen	Brave Tern	800 t	78 / 45	Block Island (2016), Bard (2013), Global Tech I (2014)	2011
Jack up vessel (self-propelled)	DEME / Geosea	Apollo	800 t	70 / 84 (extendable to 106)		2017
Jack up vessel (self-propelled)	DEME / Geosea	Neptune	600 t	Xx / 80 (extendable to 92)	Thornton Bank Phase 3 (2013), Northwind (2013-	2012

					T & F), Trianel Borkum Phase 1(2013), EnBW Baltic 2 (2014), Kentish Flats Extension (2015 - T & F)	
Jack up vessel (self-propelled)	MPI	MPI Resolution	600 t	35 / xx	Lincs (2011/12 - F & T), Humber Gateway (2013 - Foundations)	2004
Jack up vessel (self-propelled)	Otto Wulf Gmbh	Wind Lift 1	500 t	45 / 71	Bard (2013)	2010
Jack up vessel (self-propelled)	DEME/ Geosea	Goliath	400 t	xx / 78.8	Thornton Bank Phase 3 (2013) - Turbines Walney Phase 1 (2010) - Foundations	2009
Jack up vessel (self-propelled)	SeaJacks	Seajacks Leviathan	400 t	41 / xx	Greater Gabbard (2010),	2009

					Sheringham Shoal (2011), Walney Phase 2(2011), Meerwind Ost/Sud (2013), Humber Gateway	
Jack up vessel (self-propelled)	SeaJacks	Seajacks Hydra	400 t	48 / xx	Global Tech 1	2014

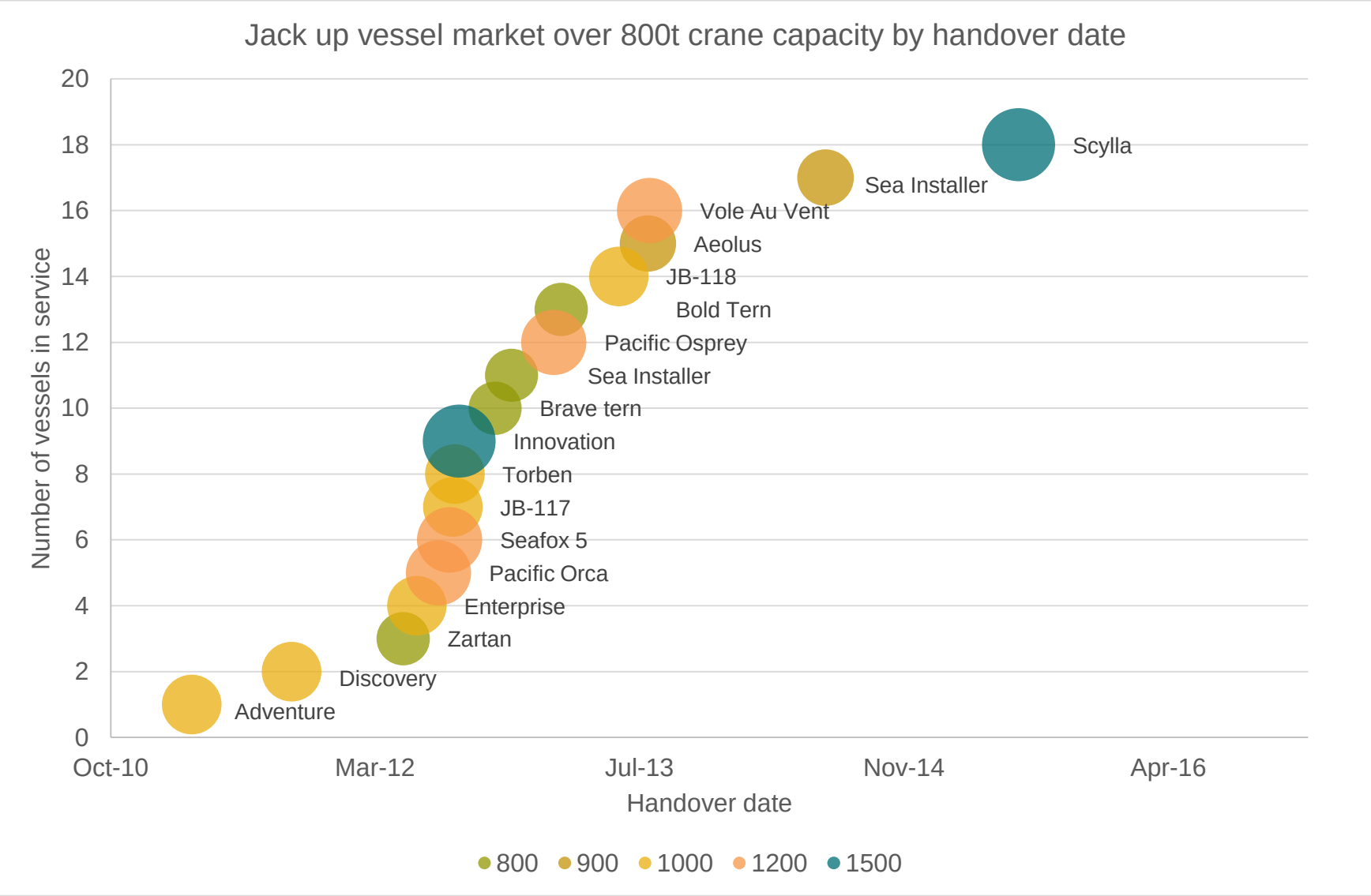

Figure 4 - Jack up vessel market over 800t crane capacity by handover date

51.5 Additional comments

None for this indicator

51.6 Recommendations

None for this indicator

52 Competition in Cable Installation

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Competition within the industry	Installation	Competition in Cable Installation

52.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there is evidence of continuing strong competition in the cable installation market. There is evidence that the number of cable installation vessels targeted for 2020 has been comfortably met. Several organisation have recently brought to market new purpose built cable installation vessels, for both array and export cable work.

Last year this indicator was also assessed as ‘ahead of target’ noting that the market was well served by capable and proven vessels.

There is a fleet of at least 20 vessels or barges with offshore wind cable installation project experience, and more than one operator launching new purpose built cable installation vessels. The general trend at the present is slight over supply, which combined with a depressed oil and gas market where some of the vessels/contractors would normally be working is continuing to deliver strong levels of competition on cable installation work for offshore wind. Similarly, it is possible that the recent investments in larger cable installation

vessels has been justified based on some work anticipated on interconnector projects which may be viewed as more attractive and stable from a contractors point of view than the relatively volatile pipeline in offshore wind.

It is also apparent from evidence that the trend described in the ‘competition in foundation installation’ indicator also has an influence here. That is an increasing requirement for companies to operate in partnerships or joint venture to be successful. That is where either cable supply and installation or cable installation and other balance of plant installation can be offered to a developer as single joined up contract packages. This is likely to push installation only contractors out of the market.

Outlook:

The outlook for the level of competition in cable installation in the coming years remains positive. It is likely that there will continue to be strong competition based on a number of proven vessels and experienced contractors.

There remains the possibility that other factors could influence the level of competition, specifically if the downturn in the oil and gas market changes, the level of competition and day rates for vessels in general could increase. In a market with high levels of competition and a relatively unpredictable future pipeline such as offshore wind there remains the possibility that some players will exit, which could reduce competition.

A ‘high confidence’ was expressed by industry in the future outlook for this indicator, suggesting that participants felt that a good level of competition was likely to continue in this area.

52.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>6 proven subsea cable vessels	>8 proven subsea cable vessels	>8 proven subsea cable vessels	>8 proven subsea cable vessels	>8 proven subsea cable vessels

On target	4-6 proven subsea cable vessels. At least one new build vessel is ordered	5-8 proven subsea cable vessels	5-8 proven subsea cable vessels	5-8 proven subsea cable vessels	5-8 proven subsea cable vessels
Behind target	3-4 proven subsea cable vessels	4-5 proven subsea cable vessels	4-5 proven subsea cable vessels	4-5 proven subsea cable vessels	4-5 proven subsea cable vessels
Missed target	<3 proven subsea cable vessels	<4 proven subsea cable vessels	<4 proven subsea cable vessels	<4 proven subsea cable vessels	<4 proven subsea cable vessels

52.3 Evidence

52.3.1 Questionnaires

Category	Questionnaire response
Provide details of any cable installation vessels which you own or have long term leases for.	
[Installation]	Siem Aimery, Siddis Mariner
[Developer]	None
How many proven cable installation vessels would you consider active in the market?	
[Developer]	More than 12

How would you rate competition using the scale above?	
[Developer]	Good

52.3.2 Interview

Category	Questionnaire response
Provide details of any cable installation vessels which you own or have long term leases for.	
[Installation]	To be competitive in this market an organisation needs to be able to provide 'supply and Install' services as these contracts tend to be the norm e.g. need to provide both the vessel and cable
How many proven cable installation vessels would you consider active in the market?	
[Installation]	Smaller vessel only providers who the parent company of do not want to invest in supply of cables are placing themselves out of the market by not offering this capability.

52.3.3 Market intelligence

Evidence	Source

• In May 2016, DeepOcean has officially named its latest piece of kit - the “most advanced power cable laying vessel in the world”. The Maersk Interconnector is getting ready for a packed programme of work, initially installing the export cables of the Walney Extension, the world’s largest windfarm, off Cumbria.	http://www.gazettelive.co.uk/business/business-news/deepoceans-latest-piece-cable-laying-11317182
• In June 2016, Bibby Offshore has announced that it is moving into the offshore wind array cable installation market. The Company has purchased a power cable lay carousel from Ecosse Subsea Systems (ESS), which will enable Bibby Offshore to lay power cables for offshore wind projects from its vessels.	http://www.4coffshore.com/windfarms/bibby-offshore-moves-into-offshore-wind-cable-market-nid3912.html
• In June 2016, DEME subsidiary Tideway has been awarded a contract to install the export cables for Dong Energy’s 1.2 GW Hornsea 1 offshore wind farm off the Yorkshire coast. The Belgian company said it will deploy its newest DP3 cable lay vessel Living Stone which is currently being built by LaNaval in Bilbao. It will be delivered in April 2017.	http://renews.biz/103038/deme-outfit-joins-hornsea-party/
• In August 2016, 50 Hz Transmission GmbH reported that the installation of the Ostwind 1 offshore cable system which will link the 385 MW Arkona and the 350 MW Wikinger offshore wind farms in the German part of the Baltic Sea to an onshore substation in Lubmin is progressing as planned. The UK-flagged cable lay vessel Cable Enterprise laid a 27 km segment of a 90 km export cable in June. This is the longest out of four sections of subsea cables to be installed. The subsea cable was manufactured by Prysmian and loaded onto the Cable Enterprise in Prysmian’s factory in Arco Felice near Naples, Italy.	http://www.offshorewind.biz/2016/08/18/ostwind-1-export-cable-installation-reaching-halfway-mark/

• In September 2016, Tekmar Energy Limited (TEL) and Subsea Innovations Limited (SIL) have signed a strategic collaborations agreement to collaborate in sales, product development and strategic initiatives towards cost and risk reduction for the offshore wind market. They plan to develop new solutions for: - Offshore cable and SURF installation equipment. (Structural equipment). - Pipeline repair systems and subsea sealing solutions. (EPRC and J-tube seals). - SURF and cable protection solutions. (Bend restrictors and hang-off systems). - Bespoke tooling for offshore installations. (Excavation, burial, deployment and cutting).	http://www.windtech-international.com/company-news/tekmar-energy-joins-forces-with-subsea-innovation
• In October 2016, the Dutch company Fugro has started cable installation work on the 400 MW Rampion offshore wind farm in the English Channel, with phase one expected to be completed in November and phase two starting in March next year. The offshore wind market remains strong for the company, despite the continuing downturn in the oil and gas services market. However, work in the renewables sector could not prevent the company's revenue falling 22.4% to €474.1 m in the third quarter of 2016, compared with €610.9 m in the same period last year.	http://renews.biz/104609/fugro-buoyed-by-offshore-wind/

52.4 Cable installation vessels

This table lists vessels known to have project experience on either export or array cable installation for offshore wind projects.

Vessel Type	Vessel (Owner or Operator)	DP Class	Windfarm experience	Constructed in
Cable lay barge	Henry P Lading (JD Contractor)	n/a	Horns Rev 1 & 2, Middelgrunden, Rodsand 2, Anholt	1930, rebuild 1964, converted 2009
Cable lay barge	Pontra Maris (Stemat Marine) chartered by VSMC	n/a	Horns Rev 2, Q7, Ormonde, Barrow, Gwynt y mor, Kentish Flats, London Array, North Hoyle, Scroby Sands	1970
Cable lay vessel	CS Pleijel (Baltic Offshore)	1	Lilgrund, Karehamn	1972, last converted 2015
Cable Lay vessel (conversion)	Atlantic Carrier (Atlantic Marine & Aviation)	2	Baltic 2, Humber Gateway	1974, converted 2001
Cable Lay Vessel / Multipurpose	Cable One (JD Contractor)	n/a	Baltic 1, Horns Rev 1 & 2, Arklow Bank	1975, last converted 2001
Cable lay vessel	Nexans Skagerrak (Nexans)	n/a	Belwind	1976, last converted 2016

Cable Lay Vessel / Multipurpose	CLV Sia (CT Offshore)	2	Borkum Riffgrund, Gode Wind, Greater Gabbard, Gwynt y mor, Lincs, Inner Dowsing, London Array, Thanet, Walney, West of Duddon Sands	1978
Cable lay barge	Eide Barge 28	n/a	Thronton Bank, Gunfleet Sands	1978
Cable Lay barge	Caspian Spider (Caspian Services) Formerly "coastal spider"	n/a	Arklow Bank	1981, last converted 2008
Cable lay barge	Bodo Installer (Bolen & Doyen). Was Oceanteam Installer	n/a	Alpha Ventus, Riffgat, Burbo Bank, Scroby Sands, Kentish Flats Extension	1982, converted 2005
Cable lay vessel	Giulio Verne (Prysmian/VSMC)	2	Alpha ventus, Amrumbank West, Dan Tysk, Nordsee Ost, Walney Phase 2	1984

Cable lay barge	AMT Explorer (Global Marine)	n/a	London Array, Rhyl Flats Vessel sank July 2014	1985
Cable lay barge	AMT Discoverer (Technip)	n/a	Greater Gabbard, Lincs, Rhyl Flats, Gunfleet Sands 3 Demo project	1985, Converted 2009
Cable Lay Vessel	CS Sovereign (Global Marine)	2	Thornton Bank 1,2 & 3, Belwind, Global Tech 1, Wikinger, Horns Rev 2, Barrow, London Array, Beatrice Demonstrator	1991
Cable Lay barge	Eide Barge 32 (Nexans)	n/a	Eneco Q7	1993
Cable lay barge	UR101	n/a	Lincs, Lynn, Inner Dowsing, Robin Rigg, Sheringham Shoal, Thanet	1993, last converted 2007
Cable Lay vessel	Cable Innovator (Global Marine)	2	Thornton Bank Phase 2, Global Tech 1, London Array	1995

Adapted CSV	Aethra - was Polar Prince (GC Riebder)	2	Greater Gabbard, Gwynt y mor, Thanet	1999
Cable lay vessel / multipurpose	Normond Pioneer (Solstad Offshore)	2	Borkum, Westernmost Rough	1999
Cable lay vessel	Topaz Installer (was Team Oman)	2	Alpha Ventus, Butendiek, Borkum, Horns Rev 2, Sheringham Shoal, Thanet	1999, last converted 2012
Cable Lay barge	Cable Enterprise (Prysmian)	n/a	Wikinger, Deutsche Bucht, Gwynt y mor	2001, last converted 2014
Cable lay vessel / multipurpose	Normand Flower (Solstad) chartered by VSMC	3	Nordsee Ost, Meerwind, London Array	2002
Cable lay vessel / multipurpose	Normond Mermaid (Solstad Offshore)	3	Thanet	2002
Cable Lay Vessel / Multipurpose	Northern Wave (Deepocean - was CTC Marine)	2	Greater Gabbard	2002, last converted 2012

Cable lay barge	Stemat 82 (Stemat Marine Services) chartered by VSMC	n/a	Ormonde , Walney Phase 1&2 , Alpha Ventus, Horns Rev 2, Anholt,	2007
Cable lay barge	Nostag10 (Nostag) chartered by NSW, TAGU	n/a	Nordergrunde, Roadsand2, Kentish Flats extension	2008
Cable Lay Vessel / Multipurpose	Deep Cygnus (CTC)	2	Greater Gabbard	2009
Cable lay barge (specifically for shallow waters)	Atalanti (S&O Ship management)	n/a	Global Tech 1	2010
Cable lay vessel	Stemat Spirit (VSMC)	2	Nordsee Ost, Butendiek, Thronton Bank Phase2, Borkum, Humber Gateway, London Array, Ormonde, West of Duddon Sands, Walney 1&2, Westernmost Rough	2010

Cable lay vessel	Willem de Vlamingh (Jan de Nuul)	2	Northwind, Burbo Bank Extension	2011
Cable Lay Vessel / Multipurpose	Olympic Taurus (Olympic Shipping) chartered by VSMC		Dan Tysk, Northwind	2012
Cable lay vessel	Ndurance (Royal Boskalis)	2	Baltic 2, Luchterdienen, Gwynt y mor, Westernmost Rough	2013
Cable Lay Vessel / stone dumping - new build	Isaac Newton (Jan De Nuul)	2	New build - scheduled for Race Bank export cables	2015
Cable lay vessel - new build	Nexus (Van Oord)	2	New build. Gemini	2015
cable lay vessel - new build	Siem Aimery	2	New build. Scheduled for Veja mate	2015 delivery

52.5 Additional comments

None for this indicator

52.6 Recommendations

None for this indicator

53 Contracting packages / interface management

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Collaboration	Vertical	Contracting packages / interface management

53.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	Ahead of target	↑	Medium confidence

Finding: Ahead of target

Marked as 'ahead of target' in 2016 because there is evidence to suggest several projects have closed and/or are being delivered with a small number of contract packages, and as such the requirement for this year that more than one project should have closed with fewer than 5 packages has been met.

There is something of a divergence in this indicator, or at least evidence that developers are clustering around one of three potential approaches:

- Developers who are finance led will value 'bankability' above all else for their projects, they may not necessarily have or want a large team of in house technical expertise and as a result will strive for as few contract packages as possible and will typically settle on 3 – 5, accepting that they will pay main contractors a significant contingency.

- Developers who are typically formed of at least part of formerly state owned utilities and have a greater technical focus, may still require a significant degree of finance input to projects but will be comfortable managing a greater number of contract packages, perhaps in the tens.
- Developers who specifically aim to target contracting directly with the final suppliers at every opportunity, and whose strong technical focus and in house technical experience are seen as competitive advantages. Such developers may run a project with over 100 individual contract packages.

It may be illuminating to reflect on what may be driving these differing approaches. There was acknowledgement from industry engagement that the level of contingency (for the project as a whole) will be greater when taking an approach that uses a small number of packages than when the developer holds more risk for management of interfaces. However, the overall cost of a project may still be less (despite increased CAPEX associated with contingencies passed on to the developer by main contractors) if the finance community are able to offer more attractive terms due to being more comfortable with the risk.

Certain developers clearly see their route to cost reduction as the reduction in financing costs, whereas others see a reduction in contingencies through comprehensive technical expertise and in house interface management as a more attractive way to reduce costs.

Last year this indicator was assessed as ‘on target’ noting similarly that the requirement for a project with a small number of packages had comfortably been met, but with less confidence that contingencies were reducing.

This year engagement with the finance community and contractors suggested that there was a feeling that contingencies were still variable but generally reducing slightly. This was attributed to the industry gaining knowledge and working experience, and as projects are now much more likely than in the past to be delivered on time and on budget.

Outlook:

For UK projects in the future it looks likely that there are now only a small number of developers (4 – 6) who will have the appetite and balance sheet to necessary to compete, as even when taking an approach with a small number of packages the level of spend required ‘at risk’ in the development phase looks likely to act as a barrier to any smaller organisations seeking to develop sites. Compounding this effect, it also looks likely that the MW size of sites in the UK in future will increase. Whereas round 1 and 2 sites comprised tens to

hundreds of MW, there are now few projects below 500 – 600 MW in size which look likely to achieve support, with a size of 800 – 1200 MW looking likely to become common for projects participating in support auctions to the end of the decade.

Significant changes in the contracting and interface management strategies of developers are not likely in the near future. It is expected that the divergent approaches described above will continue more or less unchanged for the next tranche of projects. Potential future changes may occur if more projects seeks to have greater involvement of institutional investors and/or an involvement of finance at an earlier stage in future, which may bring the industry closer to other mature power or infrastructure investment practices.

A 'medium confidence' was expressed by industry in the future outlook for this indicator reflecting the expectation that there will continue to be a variety of approaches to contract packages and interface management among the pool of developers competing for UK projects.

53.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>1 project closed with <5 packages. Contingencies reducing quickly.	>2 projects closed with <5 packages. Contingencies reducing quickly.	>2 projects closed with <5 packages. Contingencies reducing quickly.	>2 projects closed with <5 packages. Contingencies reducing quickly.	>3 projects closed with <5 packages. Contingencies reducing quickly.
On target	1 project closed with <5 packages. Contingencies reducing steadily.	2 projects closed with <5 packages. Contingencies reducing steadily.	2 projects closed with <5 packages. Contingencies reducing steadily.	2 projects closed with <5 packages. Contingencies reducing steadily.	3 projects closed with <5 packages. Contingencies reducing steadily.
Behind target	0 project closed with <5 packages. Contingencies flat.	0 project closed with <5 packages. Contingencies flat.	0 project closed with <5 packages. Contingencies flat.	0 project closed with <5 packages. Contingencies flat.	0 project closed with <5 packages. Contingencies flat.
Missed target	>1 project closed with >15 packages.	>1 project closed with >15 packages.	>1 project closed with >15 packages.	>1 project closed with >15 packages.	>0 project closed with >15 packages.

	Contingencies increasing.	Contingencies increasing.	Contingencies increasing.	Contingencies increasing.	Contingencies increasing.

53.3 Evidence

53.3.1 Questionnaires

Category	Questionnaire response
Describe your approach to contracting strategy, e.g. number of packages per project.	
[Finance]	We are prepared to finance projects on an EPC / turnkey basis with small number of packages per project. Equally we are able to finance a project adopting a multi-contracting approach providing the interface risk is appropriately mitigated with an experienced project manager. The industry (with the exception of [Developer]) appears to be gravitating towards a small to medium sized number of contracts - c. 4-8 packages.
[Developer]	Approach varies from project to project, up to 10 packages per project divided by each physical component of windfarm.
What advantages do you feel that this strategy offers for your projects?	
[Finance]	N/A - developer should respond.
Do you feel that your contracting strategy influences the contingency (both overall and individual) on your project? If so please provide details.	

[Finance]	N/A - developer should respond. As a rule of thumb, as a financier, we would expect a lower level of contingency for offshore wind projects which take more of an EPC / turnkey approach because there are fewer interfaces and a certain level of contingency is already embedded in the contract price. However, this approach does not necessarily lead to a reduction in overall capex costs as in my view the contract prices for a project with fewer contracts are more expensive than where a multi-contract approach is taken because risk pass-through to contractors is greater with an EPC approach and contractors will price this into their contracts.
[Developer]	Contingency is informed by project risk which includes a range of risk including, but not limited to, contract delays. These delays would be a risk regardless of contracting strategy.
Do you have any experiences of the level of contingency (per contract and overall) reducing in recent years? If so please provide details. How do you expect this to change in the next few years?	
[Finance]	Contingency levels are project specific in my view and also dependent on whether debt finance is required. Equity has its own view on contingency levels, but if project finance is required to fund the project then final contingency assumptions will potentially differ (increase) from those originally proposed by equity. I have not witnessed a clear or obvious trend of reducing levels of contingency (at least not significant reductions) in recent years.
[Developer]	No information available

53.3.2 Interview

Category	Interview response

Describe your approach to contracting strategy, e.g. number of packages per project.	
[Installation]	This can be a different experience depending on the customer for [Installation] as there are different attitudes towards risk. Developers who have a large and strong pipeline of projects with more experience and good internal capability when it comes to contracting and analysing the installation periods are more likely to treat vessels as a commodity. Whereas a developer with less projects, experience and internal capability tends to be more risk averse and will load more risk onto the vessel supplier – such as weather risk, mobilisation risk, option periods on back end of contracts – all things which come at a price.
[Developer]	[Developer] belongs to category of organisations want to act prudently and appropriately for their set up by having a clear ownership and risk of interfaces in the supply chain, generally by having a small number of key contract packages.
[Finance]	Comfortable with multi package contracts when the right sponsor can be found. There is a spectrum of sponsors with varying strengths, including capability to manage multi contract projects. [Finance] are looking for every party who is a significant partner to bring/contribute something, so if package/interface management is not their strength then there should still be a compelling reason as to why that organisation are involved/contributing value. Significant equity interest in offshore wind projects are not expected to be passive participants in projects just now, the industry is generally looking for people to be motivated and engaged There is limited influence of UK banks into UK offshore wind projects, and as such it is dominated by Japanese or EU banks. This can be stifling, as EU-model banks are likely to continue using a limited number of contracts, based on what has been successful for them in the past. The comfort zone of many EU banks does not permit multi contracting, with some never willing to do it.

Do you feel that your contracting strategy influences the contingency (both overall and individual) on your project? If so please provide details.	
[Installation]	Experienced developers are more likely to take on that risk as they have more internal expertise. Developers who need to go for project finance must ensure all risks have been passed on or have a value assigned, whereas if a project is financed on balance sheet this can be relaxed.
Do you have any experiences of the level of contingency (per contract and overall) reducing in recent years? If so please provide details. How do you expect this to change in the next few years?	
[Foundation]	Getting designers talking to fabricators helps in the balance between what is an optimised design and what is easy to fabricate – a mixture of both is required to minimise costs. This link historically hasn't been strong but it has recently got a little better. The current CfD regime does not help collaboration as developers do not want to collaborate together on projects and then bid in competition for the same projects. EPCI type projects where the design, fabrication and installation is more joined up through less interfaces have more of a chance within a project to optimise the design, fabrication and installation of the jacket foundation. Some projects that use the EPCI approach may have achieved this better over others that have used individual contracting packages for design, fabrication and installation.

53.3.3 Market intelligence

Evidence	Source

• In June 2016, Canada-based firm Beothuk Energy Inc., has awarded engineering contracts for its 180 MW St. George's Bay wind project, off the west coast of Newfoundland and Labrador in Canada. Maderra Engineering, the engineering arm of Beothuk Energy, will provide owner's engineering services including planning, technical documentation review and integration, as well as interface management.	http://renewables.seenews.com/news/beothuk-energy-awards-contracts-for-canada-s-first-offshore-wind-farm-527693
• In August 2016, Rob Mcabb, partner at Eversheds, told Wind Energy Update that most independent developers and utilities in Europe's offshore wind sector are responding to new financing models and more complex projects by switching from multi-contracting to 2-3 construction contracts per project. In many cases, developers would procure the supply and installation of the turbines under one contract and the Balance of Plant (BOP) components under another main package. In some countries like the U.K., where transmission assets are transferred to a separate entity in the future, the BOP contract may be broken down further so that agreements and works could be replaced more easily down the line, Mcnabb said. According to Simon Luby, director Due Diligence at K2 Management, contracting strategies in the sector have split into two main approaches. While DONG Energy and a small number of others tend to break down construction work and the supply chain into as many individual packages as possible to have more direct management and cut costs, a lot of developers are beginning to limit the number of contracts to reduce their exposure to project risks. Several years ago, developers moved from splitting work into 9-10 packages on average to allocating the work in 4-5 contracts. By contrast, a lot of the recent and current projects in the Netherlands, Germany and elsewhere are procuring under 2-3 contracts at most, Luby said. Focusing on 2-3 contracts only often carries a higher risk premium upfront because it puts the interface risks between all the different packages with the contractor rather than with the project developer. According to Mcnabb, most contractors are willing to accept the risk as they have now learned a lot more about managing the risks on projects. However, limiting the number of contracts is likely to reduce the potential overrun cost downstream in the project, compared to the multi-contracting approach, where delays from one contractor have a ripple effect on everybody else, he said. According to Luby, the multi-contract approach clearly offers the best opportunities for cost reduction, but it requires a developer with very strong engineering expertise, tendering and	http://analysis.windenergyupdate.com/construction/european-offshore-wind-developers-shy-away-multi-contracting

negotiation skills, and experienced personnel. However, with a good competitive tender process and pragmatic approach to cost versus risk, the smaller contract strategies are starting to also realize good cost reductions in addition to just cost certainty. The growing use of project financing has also reduced the use of alliancing contracting, which was becoming popular with utilities several years ago but remains largely unfamiliar to banks, which place a premium on cost and schedule certainty, and assessment of risk. Some alliancing structures remain – what Mcnabb calls 'alliancing light' – where contracts include bonus structures and KPIs based on common goals and targets, but contracts these days are less likely to feature the full sharing of risk and reward between all the stakeholders.	

53.4 Projects by contract packages

The table below splits EU FID 2016 projects based on their expected number of contract packages. Note that bottom up analysis of all individual contract packages has not been possible as not all projects have released details on contract awards at this stage.

Name	Developer	EU FID 2016 Capacity (MW)	% of EU FID 2016 (MW)	Number of turbines	% of EU FID 2016 Turbines
Borkum Riffgrund 2	DONG	450.00	8.93	56.00	7.92
Hornsea Project One	DONG	1218.00	24.18	174.00	24.61
Aberdeen Offshore Wind Farm (EOWDC)	Vattenfall	92.40	1.83	11.00	1.56

Horns Rev 3	Vattenfall	406.70	8.07	49.00	6.93
East Anglia ONE	SPR	714.00	14.17	102.00	14.43
Arkona	E.ON	385.00	7.64	60.00	8.49
Subtotal – large number of contracts			**64.83**		**63.93**
Norther	Eneco	369.60	7.34	44.00	6.22
Rentel	Rentel NV	309.00	6.13	42.00	5.94
Merkur	Merkur (Infrared)	396.00	7.86	66.00	9.34
Nissum Bredning Vind	Siemens	28.00	0.56	4.00	0.57
Tahkoluoto Offshore Wind Power Project	Suomen Hyotytuuli Oy	40.00	0.79	10.00	1.41
Beatrice	SSE	588.00	11.67	84.00	11.88

Blyth Offshore Demonstrator Project - Array 2	EDF	41.50	0.82	5.00	0.71
Subtotal – small number of contracts			**35.17**		**36.07**

53.5 Additional comments

None for this indicator

53.6 Recommendations

None for this indicator

54 Supply chain involvement

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Collaboration	Vertical	Supply chain involvement

54.1 Summary Analysis

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

Finding: Behind target

Marked as ‘behind target’ in 2016 because although there is evidence that some developers are seeking to involve the supply chain on projects at an early stage, there was still consistent comment from the supply chain that they often feel that they are not able to provide input to developers at a sufficiently early stage to provide more accurate costs and/or deliver cost reduction.

Last year this indicator was assessed as ‘on target’ noting that there was early engagement of the supply chain on some projects but that this was not always the case. The study last year also highlighted the influence of framework agreements and the pressures of a competitively driven CfD auction support system.

Developers are generally keen to establish price certainty from the supply chain well in advance of preparing their bids to a CfD auction. The supply chain evidenced varying approaches to this from developers, with some running procurement led tendering processes, requiring commitments on price based on limited detail, an approach which the supply chain felt tended to offer least value. Others take a

middle ground and involve a small number of potential suppliers in ‘FEED competitions’ where a percentage of the bidders engineering costs are covered but where competitive tension is maintained and the supply chain are conducting work at risk in order to deliver more accurately scoped proposals based on more detailed designs. There was also some evidence to suggest that some developers are happy to involve particular parts of the supply chain, particularly where significant track record and experience exists, in their projects at an early stage, and may place contracts and pay for design work ahead of preparing a CfD auction bid

There was evidence of pressures flowing down the supply chain below the tier 1 contractors. For example a tier 1 participant in a ‘FEED competition’ will be seeking fixed prices from their suppliers, and will be requiring these suppliers to commit to prices 18 months into the future. Such sub suppliers are then exposed to:

- The risk they will not win a tender from the tier 1 contractor;
- The risk that the tier 1 will not wind the FEED competition;
- The risk that the project may not be consented;
- The risk that auction rounds are delayed or do not take place;
- The risk that the project may not be awarded a CfD in a competitive auction round.

Evidence from engagements suggests that it can be challenging to motivate the supply chain to participate in offshore wind projects, particularly when they offer products or services that are applicable to other less volatile industries.

Finally, the multiplicity of bidding to win contracts in offshore wind was also described as a barrier to cost reduction. A supplier or sub supplier may have to prepare tenders several times for the same project, or for several projects when only one will go ahead. In a sustainable industry the overhead cost of repeatedly developing quotations based on engineering at risk will eventually have to be covered by some project, and as such this approach may offer short term apparent gain in cost reduction but may not be sustainable for a mature industry in future.

Outlook:

In the medium term, when projects will be developed based on CfD support it is possible that the level of supply chain involvement will increase, with more Developers choosing to work closely with their suppliers, in part as a way of compensating for the reduced degree of horizontal knowledge sharing driven by a competitive support process.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, suggesting cautious optimism about continuing progress in this area in future.

54.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>50% projects: SC pre-PQQ involvement	>75% projects: SC pre-PQQ involvement	>75% projects: SC pre-PQQ involvement	>75% projects: SC pre-PQQ involvement	>90% projects: SC pre-PQQ involvement
On target	25-50% projects: SC pre-PQQ involvement	50-75% projects: SC pre-PQQ involvement	50-75% projects: SC pre-PQQ involvement	50-75% projects: SC pre-PQQ involvement	50-90% projects: SC pre-PQQ involvement
Behind target	1-25% projects: SC pre-PQQ involvement	25-50% projects: SC pre-PQQ involvement	25-50% projects: SC pre-PQQ involvement	25-50% projects: SC pre-PQQ involvement	25-50% projects: SC pre-PQQ involvement
Missed target	0% projects: SC pre-PQQ involvement	<25% projects: SC pre-PQQ involvement	<25% projects: SC pre-PQQ involvement	<25% projects: SC pre-PQQ involvement	<25% projects: SC pre-PQQ involvement

54.3 Evidence

54.3.1 Questionnaires

Category	Questionnaire response
At what stage are the supply chain involved in projects?	
[WTG OEM]	Around 6 months prior to bidding into the auctions/CfD process etc.
[WTG OEM]	Customer dependant - some 'Framework' partnerships but some still deploying traditional transactional procurement
[Foundation]	FID stage
Designer / Survey	We get involved quite early and I would expect now as we move towards having better price certainty at the bidding stage for projects the supply chain will be more involved.
[WTG OEM]	[WTG OEM]´s supply chain development involved in the earliest stages in projects
[Installation]	Question is unclear. If a developer is being diligent in their project development phase - they will go out to supply chain to price their project on a budgetary basis early on. Certainly at the point of CfD application developers should have had extensive dealings with supply chain to ensure accurate understanding of the costs (some developers did not do this). However in any case, projects do not evolve in a silo - everything from the location of the foundations and cables to the number or turbines can severely impact costs.

[Developer]	Significant engagement with supply chain takes place throughout the project development to understand the technology options, including the next generation or new innovative solutions. The supply chain companies, particularly Tier 1, are invited to comment on preliminary designs or submit their own outline proposals using site data provided e.g. - Foundation fabricators have reviewed foundation options from a fabrication perspective - Installation contractors have reviewed foundation options from an installation perspective and provided operating limits - Potential foundation suppliers have priced concept solutions - Electrical contractors have submitted outline electrical configurations and OSS solutions - The tendering process is then implemented in parallel with FEED and detail design activities, including options on scope, to ensure the most cost-effective solutions are selected.
Do you feel that earlier involvement is advantageous? If so please provide details.	
[WTG OEM]	Yes, as it would allow a screening to be made of the projects that are realistic prospects and would allow more team to optimise the technical solutions.
[WTG OEM]	Yes - only by working as a partnership to reduce project cost can optimised solutions be reached
[Foundation]	Not necessarily; supply-chain involvement in very uncertain projects is of limited value. The most important is to have manufacturer involved in the design through EPC approach.

Designer / Survey	Yes, the earlier contractors are involved the better so better technical solutions can be found at lowest cost.
[WTG OEM]	Yes, it is really important the early contact with the different offshore wind suppliers, such as, substructures and WTG manufactures (...). Nowadays, many offshore wind farm developers organize "Supplier date" where supply chain actors can interact with others.
[Developer]	Yes. This provides the opportunity to verify proposed technology choices and design solutions ahead of formal tendering or auction bidding.
What are the barriers to improving the engagement of the supply chain?	
[WTG OEM]	Earlier collaboration
[WTG OEM]	Developer approach - not helped by nature of CfD process
[Foundation]	Multi-contracting approach
Designer / Survey	There shouldn't be any but I guess there is some confidentiality in the developer and contractor groups which they may be reluctant to share.

[WTG OEM]	One of the most important barriers to improve the engagement of the supply chain is "The Intellectual property". At present, the offshore wind technologies are really innovative. Thus, the information exchange process could become complicated.
[Developer]	Our experience is that most contractors are willing to engage developers for early stage discussions

54.3.2 Interview

Category	Interview response
At what stage are the supply chain involved in projects?	
[Installation]	The level of supply chain involvement tends to be dictated by a developer's experience. This will large pipeline and more experience are less dependent on supply chain input. This with smaller pipelines and less track record will rely more on supply chain input.
Do you feel that earlier involvement is advantageous? If so please provide details.	
[WTG OEM]	[PROJECT] was a good example of turbine OEM working very closely with the customer [WTG OEM] also signed a framework agreement with [COMPANY] some years ago, and this was a way that they were able to justify and invest in developing the products that are now available, by having some visibility of a pipeline. The level of engagement even with tier 1 supply chain and when engagement happens depends on developers but this is something that [WTG OEM] as an OEM try hard to encourage, sometimes well received and other times where

	procurement/finance function makes the decision then everything must be tendered as they feel that this is best way to lowest cost of package (does not mean lowest cost project). Other developers may have more progressive ideas about strategic procurement management and relationships rather than just always seeking the lowest cost through procurement processes, as the way to the best project overall.
What are the barriers to improving the engagement of the supply chain?	
[Electrical]	The move from previous regime to CfD has made a huge difference, developers want to go into CfD with a fixed and firm price, so are coming early for prices from suppliers, running competitions and asking for prices to be held for 18 months' time. Supplier holds a lot of risk on this pricing for a long time. FEED competitions are a theme amongst developers preparing for CfD. The problem flows all the way down the supply chain, so supporting organisations and tier 2 and 3 are causing risk to be priced in that they have not got a firm cost and cannot commit. Hard sell for the business, may not have appetite to play in this lottery of sites that do not have consent or CfD, especially as they are required to contribute cost of engineering at risk.

	FEED competitions are challenging to sell to the approvals process of a company which does not work solely in offshore wind, HVDC FEED competition could require millions of pounds of input for a project very far in the future with uncertain chances of success. Challenging to subcontract down the supply chain as everything is still pending, they could have other more certain jobs (in other industries) to spend their time on. The level of upfront work required for small suppliers particularly could be driving consolidations.

54.3.3 Market intelligence

Evidence	Source
• Scottish Power Renewables has awarded SeaRoc Group with a five year framework contract to provide Health, Safety and Quality management support to its East Angia One offshore wind farm. Scope of work includes provision of specialist personnel to provide advice and support to the project during construction, development of management systems and to deliver comprehensive training to help ensure safe and efficient work on the project.	http://www.4coffshore.com/windfarms/searoc-group-secure-east-anglia-one-framework-agreement-nid4295.html
• Energy giant Statoil has been announced as one of the investors in a £1.3 billion project to build an offshore wind farm off the coast of North Norfolk in the east of England, creating a myriad of opportunities for suppliers. Over in	http://www.achilles.co.uk/en/about-

Germany, Statoil has entered the German energy market for the first time, investing heavily in the Arkona offshore wind farm project, purchasing 50% of the site from E.ON. The project has increased Statoil's production capacity by 65%, boosting the company's profile and share of the Nordic energy market, making the supplier opportunities it has available highly coveted. In total, Statoil's portfolio now has a combined output of 1,100 MW, helping to power more than one million properties throughout Europe with clean energy. These opportunities will be tendered for by Statoil, who is currently a buyer member on Achilles communities including Achilles UVDB in the UK and Sellihca in the Nordics. For subscriptions to the Achilles community, suppliers will need to complete a pre-qualification questionnaire, which is designed to gather information on their finance, health, safety and environment, quality management, insurance, products and services, Corporate Social Responsibility (CSR) and legal information.	achilles/industry-insights/4309-statoil-investment-in-uk-and-germany-creating-opportunities-for-suppliers
• In September 2016, DONG Energy has announced that it will be investing some £5.4 billion in the development of new offshore wind farms off the coast of the north-west of England, creating new opportunities for utilities suppliers in the process. Dong Energy operates a qualification system framework that enables them to streamline the way they engage with suppliers in different locations/projects. Dong Energy currently use 3 different qualification systems operated by Achilles: - Achilles Sellihca for all global categories as well as locals in Scandinavia - Achilles Connexio for local categories in Germany - Achilles UVDB for local categories in the United Kingdom DONG Energy is a buyer member of the Achilles UVDB community for the UK utilities sector. Suppliers that want to benefit from the opportunities the organisation has on offer in the UK need to make sure they have qualified in order to become a qualified supplier for DONG Energy. As part of becoming qualified on Achilles UVDB, suppliers need to	http://www.achilles.com/en/about-achilles/industry-insights/4486-opportunities-for-uk-utilities-suppliers-as-dong-energy-announces-5-4bn-investment

complete a pre-qualification questionnaire, with the information gathered during this process made visible to buyers within the community to enable them to make informed decisions related to their procurement activity..	

54.4 Additional comments

None for this indicator

54.5 Recommendations

None for this indicator

55 Standard contracts

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Collaboration	Horizontal	Standard contracts

55.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target	⇨	▪ Low confidence

Finding: On target

Marked as ‘on target’ in 2016 because although there is limited evidence of a significant move towards fully standardised contracts developed bespoke for the offshore wind industry, there are examples throughout the sector of organisations working together under consistently similar contracts and that in some areas greater efficiency is being achieved as a result of increasing levels of experience.

There was however significant comment during industry engagement that in some instances the efficiency of contracting had declined, in some cases significantly, so while ‘on target’ this year there is clearly potential scope for significant cost reductions to be contributed by this area in future.

Last year this indicator was also assessed as ‘on target’ noting as consistent with this year that contracts are commonly negotiated and developed from some standard forms, and that it may be unrealistic to expect that any industry will converge on fully standardised contracts for all projects.

Outlook:

A fully standardised approach as seen in other industries continues to look unlikely in offshore wind in the near to medium term. It is likely that some projects will see greater use of either standard clauses and/or a negotiation based on some standard initial contract form.

There remains significant potential to reduce costs through increasing the efficiency of contracting, and engagement with the supply chain demonstrated that they felt that procurement led approaches may not always be offering the purchasing organisation the best value.

A 'low confidence' was expressed by the industry in the future outlook for this indicator. Participants generally and the supply chain in particular see an increase in contracting efficiency as something which is unlikely to deliver cost reduction in future, and in many cases cited an expectation that legal overhead will increase in future.

55.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>50% projects: standardised contracts	>50% projects: standardised contracts	>50% projects: standardised contracts	>50% projects: standardised contracts	>90% projects: standardised contracts
On target	At least 1 project will achieve an improved efficiency in contracting. 25-50% of projects rely on industry specific or standard contract forms or using other strategies that result	More than 1 project will achieve a greater efficiency in contracting. 25-50% of projects rely on industry specific or standard contract forms or using other strategies that result	Several projects will achieve a greater efficiency in contracting. 25-50% of projects rely on industry specific or standard contract forms or using other strategies that result	Several projects will achieve a greater efficiency in contracting. 25-50% of projects rely on industry specific or standard contract forms or using other strategies that result	The majority of projects will achieve a greater efficiency in contracting. 50 - 90% of projects rely on industry specific or standard contract forms or using other strategies that result

	in a reduced contract negotiation overhead.	in a reduced contract negotiation overhead.	in a reduced contract negotiation overhead.	in a reduced contract negotiation overhead.	in a reduced contract negotiation overhead.
Behind target	First standard or industry specific contracts emerge. Limited evidence of improved efficiency on contracting.	First projects contract using standard contracts, leading to first indication of improved contracting efficiency.	More than 1 project will achieve a greater efficiency in contracting. 1-25% of projects rely on industry specific or standard contract forms or using other strategies that result in a reduced contract negotiation overhead.	Several projects will achieve a greater efficiency in contracting. 1-25% of projects rely on industry specific or standard contract forms or using other strategies that result in a reduced contract negotiation overhead.	Several projects will achieve a greater efficiency in contracting.25-50% of projects rely on industry specific or standard contract forms or using other strategies that result in a reduced contract negotiation overhead.
Missed target	No industry activity	Industry activity is maturing, no evidence of improved contracting efficiency.	First standard contracts emerge	No projects have used standard contracts	<25% projects: standardised contracts, still limited evidence of increased contracting efficiency.

55.3 Evidence

55.3.1 Questionnaires

Category	Questionnaire response

Describe your approach to standardising contacts.	
[WTG OEM]	We take a project-specific approach as each client is different
[O&M]	High commitment. most key clients have framework contracts with [O&M]
[Insurance]	We really aim for standard Insurance wordings, although the insurance broker community typically tries to gain competitive advantage by adjusting wordings in the favour of their client. We have to accept this to some extent but in general look more favourably on 'tried and tested' wordings. We aim for standard MWS scope of Works, but Again some in the Insurance broker community prefer to amend this for individual Projects.
[WTG OEM]	Contracts are negotiated line by line from a 'standard' contract start FIDIC etc.
[Finance]	N/A
[Foundation]	No input
Designer / Survey	We would much prefer to have frame agreements or MSA with our clients and then use call off contracts. The current system of negotiation for each contract is time consuming.

[WTG OEM]	[WTG OEM]´s contracts includes standard clauses which involve the supply of wind turbines, installation, operation and maintenance, warranty period and its possible extension. Furthermore, other activities could be included in the supplier scope. Therefore, the [WTG OEM] efficiency in contracting facilitate the negotiation.
[Developer]	We use two main forms of contract for our offshore projects - FIDIC & NEC –Although we do make company specific amendments to the standard forms, we try to minimise this and as far as possible duplicate contract terms and processes across the major work packages. We also frequently refresh our precedent contracts to take account of bidder comments, etc and these refreshes are rolled out across all work packages for consistency. The majority of contract schedules have also been standardised for use on all work packages.
Do you feel that the efficiency of contracting has changed in recent years? Do you expect this to change in the next few years? If so please provide details.	
[WTG OEM]	No. Each client wants different things. There are almost no commonalities in approach
[O&M]	Efficiency drastically declining. procurement playing an increasing role
[Insurance]	Insurance industry is very efficient at contracting - big decisions can be made in Little time compared to other parts of the supply chain
[WTG OEM]	Not really - Think this will always be the case.

[Finance]	N/A
[Foundation]	Standard contracts and terms are emerging, although suppliers and customers like to spend long hours in negotiating details.
Designer / Survey	Many clients procurement process is very slow and laborious, as price becomes even more of a factor this will only get worse.
[WTG OEM]	Yes, as the offshore wind sector gains experience, the efficiency of contracting will be higher.
[Developer]	Yes, as the offshore wind industry matures developers and contractors are becoming increasingly familiar with the chosen contract forms and commercial positions and this has helped make the process more efficient to some extent. Going forward, we expect this pattern to continue, particularly as contractors bid for repeat work with the same developer.

55.3.2 Interview

Category	Interview response
Describe your approach to standardising contacts.	
[Insurance]	Two main types of contract: Insurance policy between [Insurance] and project requiring insurance – construction or operational cover

	Marine warranty surveyor's scope of works Insurance policies generally follow a standardised form with amendments on almost every risk. There are no two identical policies in their portfolio. The core structure has come about after writing several policies.
[O&M]	[O&M] are on a framework with OEMs which can improve contracting efficiency. Owner/Operators are tender based with occasions of preferred suppliers but they are not on any frameworks.
[Developer]	[Developer] on their project(s) have been mainly using FIDIC, but do not have their own standard, have adapted to their site and requirements. This has helped as the contractor is familiar with this type of contract
Do you feel that the efficiency of contracting has changed in recent years? Do you expect this to change in the next few years? If so please provide details.	
[Insurance]	The insurance industry functions as a mature industry. It is good at getting contracts agreed in a short period of time. When a claim occurs, interpretation of the policy may be more complex and necessitate lawyers.
[Insurance]	The complexity of contracting is very much dependent on the owner/operator. Some have framework agreements which make purchasing less complicated, some do not and in those instances the contracting process has got worse.

55.3.3 Market intelligence

Evidence	Source

None for this indicator	

55.4 Additional comments

None for this indicator

55.5 Recommendations

None for this indicator

56 Knowledge sharing

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Collaboration	Horizontal	Knowledge sharing

56.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016 because there are several established knowledge sharing forums delivering benefits to various parts of the industry. There are examples where cross industry collaboration and dissemination has delivered cost reductions, for example in the areas of floating lidar or foundations. A consistent theme throughout engagement and evidence gathering this year was that the introduction of competitive support structures has been detrimental to the sharing of knowledge, Developers are seeking to protect their knowledge as an effort to maintain competitive advantage over those with whom they will compete for support contracts.

Last year this indicator was also assessed as ‘on target’ noting similar trends, that several forums existed and had delivered benefit, but that the willingness to share knowledge was decreasing following the move to a competitive auction support structure.

Knowledge sharing will always be something of a balance between competition and collaboration. Evidence from engagement this year suggests that increasingly Developers in particular seem to value the competitive edge that their knowledge brings them than any

advancement that could be made through collaboration. Exceptions to this rule may exist in site development technologies and operations and maintenance where competition between Developers is less acute than in some other areas or project phases.

Outlook:

Between now and 2020 it is expected that the level of knowledge sharing will decrease. Academic work is likely to continue, but the engagement of industrial partners may be challenging. The trend for any knowledge sharing to take place in select closed groups that do not publically disseminate findings looks likely to continue.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator. This is reflective of the existence and tangible benefit from some knowledge sharing activities being expected to continue, but also caution about a trend for reducing collaboration being likely in an increasingly competitive industry.

56.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	KSFs for majority of disciplines in mature phase 4 developers evidence the benefits of feedback from knowledge sharing into operational processes	KSFs for all disciplines in mature phase 5 developers evidence the benefits of feedback from knowledge sharing into operational processes	KSFs for all disciplines in mature phase 6 developers evidence the benefits of feedback from knowledge sharing into operational processes	KSFs for all disciplines in mature phase All developers evidence the benefits of feedback from knowledge sharing into operational processes	KSFs for all disciplines in mature phase All developers evidence the benefits of feedback from knowledge sharing into operational processes
On target	KSFs for at least 3 major package	KSFs for majority of disciplines in mature	KSFs for majority of disciplines in mature	KSFs for majority of disciplines in mature	KSFs for majority of all appropriate

	areas (e.g. installation, etc.) in start-up phase. 3 developers evidence the benefits of feedback from knowledge sharing into operational processes	phase. Remaining areas in start-up phase 4 developers evidence the benefits of feedback from knowledge sharing into operational processes	phase. Remaining areas in start-up phase 5 developers evidence the benefits of feedback from knowledge sharing into operational processes	phase. Remaining areas becoming mature 6 developers evidence the benefits of feedback from knowledge sharing into operational processes	disciplines in mature phase All developers evidence the benefits of feedback from knowledge sharing into operational processes
Behind target	Pioneer KSF in mature phase but KSFs for majority of disciplines in start-up phase 2 developers evidence the benefits of feedback from knowledge sharing into operational processes	At least one other KSF in mature phase but KSFs for majority of disciplines in start-up phase. Some KSF struggling to gain traction 3 developers evidence the benefits of feedback from knowledge sharing into operational processes	Pioneer KSF in mature phase but KSFs for majority of disciplines in start-up phase. Some KSF struggling to gain traction 4 developers evidence the benefits of feedback from knowledge sharing into operational processes	Pioneer KSF in mature phase but KSFs for majority of disciplines in start-up phase. Some KSF struggling to gain traction 5 developers evidence the benefits of feedback from knowledge sharing into operational processes	Some mature KSFs but some KSFs have not delivered successfully and other in start-up phase 6 developers evidence the benefits of feedback from knowledge sharing into operational processes
Missed target	Little or no KSF activity for majority of disciplines No developers evidence the benefits of feedback from knowledge	Little or no KSF activity for majority of disciplines No developers evidence the benefits of feedback from knowledge	KSFs for majority of disciplines in planning phase 1 developer evidences the benefits of feedback from knowledge	Pioneer KSF in mature phase but KSFs for majority of disciplines in start-up phase 2 developers evidence the	Little or no KSF activity for majority of disciplines 3 developers evidence the benefits of feedback from knowledge

	sharing into operational processes	sharing into operational processes	sharing into operational processes	benefits of feedback from knowledge sharing into operational processes	sharing into operational processes

56.3 Evidence

56.3.1 Questionnaires

Category	Questionnaire response
Please provide details of any knowledge sharing forums which you are an active member of (e.g. regularly attend and contribute).	
[WTG OEM]	RUK Offshore Wind Policy Forum, Carbon Trust OWA Turbine Advisory Group, Catapult Industry Advisory Group, WindEurope
[O&M]	Offshoreenergy.dk, vindmolleindustrien, renewableuk, various conferences
[Insurance]	EWTC = European Wind Turbine Committee (Insurance forum) Carbon Trust IMIA = International Association of Engineering Insurers Dansk Standard (DS)

[WTG OEM]	OWIC, OWPB, Renewable UK board and groups, OREC steering group etc.
[Finance]	Offshore Wind Programme Board. Chatham House / LCFG.
[Foundation]	No input
Designer / Survey	We regularly attend Renewable UK events, IMCA meetings and other trade and learned society meetings. There are many working groups across the industry which we participate in.
[WTG OEM]	[WTG OEM] is sharing knowledge about Offshore technologies, OEMs, ancillary industries in many Universities, such as College of Aeronautical, Naval and Industrial Engineering, as well as, different Associations and cluster such as WindEurope, Renewables UK, Syndicat des Energies Renouvelables, cluster mariteme Français, Office franco-allemand pur la transition énergétique, Erneuerbare Energien Hamburg, BWE Bundesverband Widenergie, WAB Windenergie Agentur, VDMA Verband Deutscher maschinen-und Anlagenbauer, Women of Wind Energy Deutschland
[Finance]	OWPB
[Installation]	Renewable UK, IMCA, European Subsea Cables Association, International Cable Protection Association, German Marine Technology Society, Team Humber Marine Alliance
[Developer]	RenewableUK Scottish Renewables WindEurope

	Centre for Doctoral Training in Wind & Marine Systems (Univ. of Strathclyde & Univ. of Edinburgh) Technology Innovation Centre – Low Carbon Power & Energy G9 Health & Safety OREC – SPARTA / BLEEP
Please provide details of other knowledge sharing forums which you are aware of but are not an active member.	
[WTG OEM]	OWIC, OWPB
[O&M]	IJUBOA
[Insurance]	LEG = London Engineering Group (Insurance)
[WTG OEM]	None
[Finance]	Not aware.
[Foundation]	No input
Designer / Survey	The ones we are aware of we are participating in.

[WTG OEM]	Cluster de la Energía, Vanguard Iniciative, Carbon Trust ...
[Finance]	none
[Developer]	Too many to provide information to in this response, we are aware of knowledge sharing forums through industry groups and general engagement.
Do you feel that existing knowledge sharing forums are providing benefit to the industry? If so please provide details.	
[WTG OEM]	Not really.
[O&M]	Not really. companies protect know-how
[Insurance]	Yes, to some extent
[WTG OEM]	Yes - Combined activity through OWIC/OWPB increasingly effective as the main route for dialogue with Government
[Finance]	Yes.
[Foundation]	No input
Designer / Survey	Limited benefit as the sharing of knowledge is limited generally.

[WTG OEM]	Yes, the existing knowledge sharing forum are provided benefit as the lesson learned and information sharing are good and positive in order to achieve further improvements.
[Finance]	They do provide benefit with respect to communication to government.
[Installation]	Slowly but surely the supply chain seems to be understanding that they need to share information for the benefit of the industry to enable longevity. However there are still members of the supply chain who are unwilling to share lessons learned and/or statistics ostensibly on confidentiality concerns.
[Developer]	Yes, they provide valuable routes to critical mass around specific industry developments, regulatory issues, policy alignment and influences, supply chain development and standardisation. For example, OWA has delivered substantial momentum around 66 kV for example. Similarly the Health & Safety forums / RenewableUK have been useful vehicles in aligning industry messages and sense of direction to Government and Supply Chain alike.
Have you experienced any examples of knowledge sharing helping to reduce the LCoE on projects? If so please provide details.	
[WTG OEM]	OWA group does good work on this but it hasn't met in a while
[O&M]	Only directly with business partners
[Insurance]	Knowledge sharing from [Insurance] to individual Projects about claims that have occurred on other similar assets has resulted in risk improvements e.g. better monitoring, spare part availability, business continuity planning etc. This helps reduce the risk of the project and therefore also their Insurance Premium.

	A typical comment at the end of our recommendation reports for offshore windfarms is "Implementing of recommendation can lead to a discount on the premium, which [Insurance] of course is willing to discuss further in details"
[WTG OEM]	Must be helping but hard to quantify... LCOE comes down through building projects,
[Finance]	No, but the knowledge sharing forums I participate in tend to have more of a regulatory angle to them; i.e. feeding back to UK Govt. Question better answered by developers and contractors.
[Foundation]	No input
Designer / Survey	Not so far
[WTG OEM]	[WTG OEM] gains experience with commissioned project to the reduce LCOE.
[Finance]	Yes - the PISA initiative to reduce foundation size/cost.
[Installation]	I would say the work being undertaken by IMCA's Walk to Work subgroup should result in LCOE reductions in due course.
[Developer]	Key examples can be found in the Technology Innovation Centre partnership whereby collaborative projects between Univ. of Strathclyde, SPR and SSE have focused on overall LCOE in order define innovation projects. Projects such as Weather Forecasting for Operations, Vessel Use planning tools are now being implemented in project design and contracting which are delivering LCOE reduction.

56.3.2 Interview

Category	Interview response
Please provide details of any knowledge sharing forums which you are an active member of (e.g. regularly attend and contribute).	
[Insurance]	Rather than an industry forum, with each project they aim to share information and lessons learnt. If selected as leading insurer, [Insurance] will meet with project team and go through problems they have seen elsewhere and suggest steps that can be taken to mitigate risks in terms of spare parts, business continuity plans or preparing for claims that might occur. He feels that is an area where insurers can add value. They share this experience with project teams with the aim of improving the risk profile and reducing the frequency of claims which therefore gives them the ability to reduce premiums further.
[O&M]	[O&M]s experience is that forums output recommendations but there is often little evidence of tangible actions coming out of them. [O&M] have lots of clients storing operational data but they are aware of very limited cases where they have shared data to improve services from ISPs.
[Foundation]	[Foundation] have participated in quite a lot of industry projects, academic, PhD etc. and joint industry but collaboration to date has been primarily driven by academic engagements. It is expected that the academic angle and research will

	continue, as competition here is the same as it has always been, that is institutions are only competing with other universities and institutes etc. [Foundation] have also participated in projects with a more industrial focus, e.g. under OWA/carbon trust, 2x met masts supported by a handful of developers collectively. This has led to a lot of de-risking of suction foundation technology, and have seen great advantage by having direct interaction with the client who are the eventual end customers, and it has offered a great opportunity for them to de-risk new technology. As a member of the supply chain [Foundation] fundamentally rely on developers to deploy their foundations both at test and then at full scale. In the short term it is expected that the big developer are going to continue to participate in these kind of joint projects but that the willingness to share information is reducing. This could lead to something of a stalemate where knowledge is not really shared to a sufficient degree in future, as each individual developer seeks to hold onto as much technology specific knowledge as they can as they see this as an advantage in an increasingly competitive situation. An example of this, [Developer] have deployed a suction bucket jacket previously, and would be expected to have good related experience. [COMPANY] are now doing their own for a different project, but they will likely each keep the knowledge to themselves and hope that they will be smarter that the other parties. In other sectors, e.g. automotive some parts are shared, the less important bits are shared, particularly when they come from the supply chain, and everyone works on specialist pieces or subsystems for themselves where they believe their own organisation is genuinely the strongest and best placed to do so. Wind might get there but is some way from this level of maturity at present. In the short term support mechanisms are not encouraging collaboration as each developer must compete on power price against the others. There has recently been a major wakeup call for a lot of developers, this is focussing on/driven by some extremely aggressive and low power price bids. There may perhaps be another wakeup call, perhaps not materialising for another 5 years or so when those that have bid and won actually have to deliver projects with these aggressive prices. They could see that their profitability is impacted,

	which is something that historically those types of company have not been comfortable with accepting. This could drive radical change. Collaboration is going to be key to maintaining a sustainable whilst still competitive (on power price and in the supply chain) industry.
Do you feel that existing knowledge sharing forums are providing benefit to the industry? If so please provide details.	
[WTG OEM]	OWA with carbon trust is a great example of people coming together and developing solutions, but it is a real missed opportunity that the findings are generally not known or made public, very scant and in some cases no detail at all makes it to the public domain. A potential criticism of this approach is that it does use public money but has been used to commercial advantage, for example in giving leg up to individual (example 66kv) manufacturers, so they are advanced, but the improvements they have been able to make has not been shared widely (e.g. with their competitors). There is a feeling in the market that some innovations are being kept within certain developers, even for example in access systems, unless you have been funded by carbon trust it is difficult to develop these things on your own due to the level of expense and commitment required at risk of not having guaranteed customers. It would be good to encourage knowledge sharing, it has been positive overall in this industry, but would be nice to see it being tweaked and more all-encompassing. The government should encourage innovation, and to an extent there is little point in asking for cost reduction without some acknowledgement that innovations will need to be developed (funded?) to enable this.
[Installation]	There has recently been more evidence of sharing of work and information between turbine OEM and installation contractor for the benefit of projects. There may have been a softening slightly of what turbine OEMs may be willing to

	share. For example information on their blade installation tools was previously off limits, but is now less so, perhaps a sign of evolution or a more mature industry.
[Developer]	Have seen some very positive examples of collaboration in the operations phase, including with other developers e.g. Centrica. Can see a good level of collaboration on O&M that is clear. In the design and procurement phase companies struggle to see the advantage and it more challenging to work collaborative and/or share information and lessons. Have recently been invited by [Developer] to see their Belfast base for the [PRODUCT] which is a good example of how best practice is being shared, but perhaps it is taking place as rival developers see that this is only a slight advantage to their competition. The market dynamic of competition and uncertainty do not help the attitude and appetite to tend towards knowledge sharing in general in the developer community.
Have you experienced any examples of knowledge sharing helping to reduce the LCOE on projects? If so please provide details.	
[Installation]	The CfD process has driven more competitiveness amongst developers which has limited involvement in knowledge sharing initiatives. [Installation] have had more experience of vertical collaboration on knowledge sharing with companies who have them as their preferred supplier.

[Insurance]	As a company, [Insurance] market themselves on this ability and experience built up in the industry. [Insurance] is involved in around 75% of offshore wind farms, however they don't take 100% share in the risks as they are so large. Their market share of project risk is somewhere between 15-30% (very approximate). On projects with multiple insurance providers, brokers take responsibility for ensuring the model works well.
[Designer]	[Designer] have seen that knowledge sharing has reduced in the industry due to the competitive process of CfDs. Many developers are now asking the question, why share knowledge when that knowledge could offer a competitive advantage? The lack of knowledge sharing however might lead to inefficiencies in the supply chain due to a lack of the necessary information reaching the supply chain to improve their products and services.
[Developer]	[Developer] have done quite an in depth review and forward look of cost reduction internally, keen to align this with and findings of CRMF, potential for further collaboration.
[Developer]	The world is becoming more competitive which creates a tension between collaboration and collusion. In general, we see the opportunities for collaboration to exist in early stage development where the industry faces similar challenges and barriers to deployment and less as the development comes closer to presenting a competitive product to market.
[Electrical]	Don't see a lot of knowledge sharing as all players are in a commercial competition.

56.3.3 Market intelligence

Evidence	Source

None for this indicator	

56.4 Additional comments

None for this indicator

56.5 Recommendations

None for this indicator

57 Technical standards

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Technology	Collaboration	Horizontal	Technical standards

57.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target		Medium confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there are a significant number of technical standards in use across the offshore wind industry, some of which have been developed to a mature phase and others which are relied upon which were originally the product of related industries. There are several technical standards actively in development with the areas of foundations, cables, wind measurement, and health and safety particularly active.

Since the offshore wind industry is still relatively immature and both the technology and the shape of the industry continue to evolve fairly rapidly there are at times examples of overly prescriptive standards becoming a hindrance. Having taken several years to develop standards may become irrelevant to the type of technology available or in use relatively rapidly. Staying on top of an appropriate body of standards and maintaining their relevance will continue to be important.

Last year this indicator was also assessed as ‘ahead of target’ noting that a significant number of industry standards and guidelines exist, and that the potential for cost reduction through cross industry and cross market standardisation remains significant.

Outlook:

The outlook for this indicator is reasonably positive. There are a number of standards and guidelines in existence, which are likely to continue to be relied upon in future. Tempering this enthusiasm slightly is the ongoing requirement to maintain standards and ensure their relevance, particularly in cases where standards committees are controversial or dysfunctional. It will be important for future cost reduction that standardisation and simplification where possible is carried out, but also that standards are not overly restrictive in areas where innovative solutions could offer a benefit.

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator, suggesting a reasonably positive continuing development of the standards landscape.

57.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	11-15 industry guidelines / standards in use. 4 - 9 other ones at various stages of development with industry	13-17 industry guidelines / standards in use. 2 - 6 other ones at various stages of development with industry	16-20 industry guidelines / standards in use	>18 industry guidelines / standards in use	>20 industry guidelines / standards in use
On target	5-10 industry guidelines / standards in use. 2-5 nearly complete	11-15 industry guidelines / standards in use. 4 - 9 other ones at	11-15 industry guidelines / standards in use. 4 - 9 other ones at	13-17 industry guidelines / standards in use. 2 - 6 other ones at	16-20 industry guidelines / standards in use

	with input/buy in from industry. 2-5 others in planning phase	various stages of development with industry	various stages of development with industry	various stages of development with industry	
Behind target	5-10 industry guidelines / standards in use. 2-5 in start-up phase seeking input/buy in from industry	5-10 industry guidelines / standards in use. 2-5 under development with input/buy in from industry	5-10 industry guidelines / standards in use. 2-5 nearly complete with input/buy in from industry. 2-5 others in planning phase	11-15 industry guidelines / standards in use. 4 - 9 other ones at various stages of development with industry	11-15 industry guidelines / standards in use. 4 - 9 other ones at various stages of development with industry
Missed target	No industry guidelines / standards in use. 1-4 under development	1-4 industry guidelines / standards in use	5-10 industry guidelines / standards in use. 2-5 in start-up phase seeking input/buy in from industry	5-10 industry guidelines / standards in use. 2-5 in start-up phase seeking input/buy in from industry	5-10 industry guidelines / standards in use

57.3 Evidence

57.3.1 Questionnaires

Category	Questionnaire response
Do you think that offshore wind has a sufficient body of technical standards? If possible, approximately how many standards do you rely on?	

[WTG OEM]	TBD
[O&M]	Don't know
[Insurance]	There is room for more. We probably really look for just 2 (WTG certification and project certification)
[WTG OEM]	Mostly IEC
[Finance]	N/A
[Foundation]	Yes - DNVGL standards play a big role.
Designer / Survey	Yes, but I don't really know how many we use.
[WTG OEM]	At present, the offshore wind industry has a body of technical standard, such as, for fixed IEC 61400-3, DNV GL-ST-0437 and for floating IEC 61400-3-2. However, the technical standards require frequently updating and monitoring.
[Finance]	I cannot answer this – I am commercial side. Not technical.
[Installation]	The list is huge if listed individually. There are standards applying to the cables, the trenching tool, ROVs, the vessels, general mechanical guidelines, termination & testing, working at height, working in enclosed spaces, lifting procedures and many many more

[Developer]	Yes
Are there any areas where you think further drafting or improvement of technical standards are required? Please provide details.	
[WTG OEM]	Standards for floating offshore wind
[O&M]	requirements for certificates, HSE standards
[Insurance]	Not sure
[WTG OEM]	Not aware
[Finance]	N/A
[Foundation]	No
Designer / Survey	Not really
[WTG OEM]	Regarding floating technologies further drafting or improvement of technical standards, the industry is really innovative.
[WTG OEM]	N/A

[Finance]	As above
[Installation]	In certain standards applicability is limited, or does not account for recent industry innovations. Usually industry innovation remains ahead of the curve. One case study would be around the certificates/approvals regarding gangways on board vessels - these have popped up following the increase in market demand for SOVs with gangways, however they don't necessarily cover the vessel/gangway interface accurately enough.
[Developer]	No, not beyond areas being developed
Do you expect the standards landscape to change in the next 3 - 5 years? If so please provide details.	
[WTG OEM]	Yes. More standards will be produced for innovative areas such as floating
[O&M]	Requirements for certificates, HSE standards
[Insurance]	Not sure
[WTG OEM]	No
[Finance]	N/A
[Foundation]	No

Designer / Survey	No
[WTG OEM]	Yes, please, see previous answers.
[Finance]	As above
[Installation]	Yes - but this should be a matter of course.
[Developer]	No

57.3.2 Interview

Category	Interview response
Do you think that offshore wind has a sufficient body of technical standards? If possible, approximately how many standards do you rely on?	
[Installation]	In general there is a lot of good guidance and best practice on jack-ups, CTVs and how to operate vessels that have been produced.

Are there any areas where you think further drafting or improvement of technical standards are required? Please provide details.	
[Insurance]	[Insurance] feels that the marine warranty surveyor's scope works well as they see it as directly mitigating the risk profile associated with offshore installation work. It is moving towards standardisation but there is still some variation. He feels this could be aligned.
[Insurance]	They use DNV-GL specifications which seem to work. He is interested to see how standards for A/C export cables develop as that is an area of concern due to number of damages and near misses seen in the last few years across different suppliers and sites. It is a key risk for them.
[Developer]	In order to have meaningful standards you have to have volumes, [Developer] as a developers is still on a learning curve, other competitors may have a lot of standards and processes developed in house. There may be room for more and better standards, but this may be more of an [Developer] thing than an industry one.

57.3.3 Market intelligence

Evidence	Source
• In June 2016, Government Energy Ministers from Germany, Netherlands, Luxembourg, Norway, Sweden, France, Denmark, Ireland and Belgium gathered in Luxembourg today (6 June) to sign a Memorandum of Understanding	http://www.edie.net/news/11/9-EU-countries-to-sign-offshore-

(MoU) and Work Programme which outlines a number of actions to help reduce costs in offshore wind, including collaboration on spatial planning, grids, finance, technical standards and regulation such as health and safety rules.	wind-agreement/
• In June 2016, DNV GL published Standard for the warranty approval of marine operations, the first to deploy a digital solution that provides users with information most relevant to a specific project.	http://www.offshorewind.biz/2016/06/28/dnv-gl-issues-digitalized-marine-warranty-standard/
• In August 2016, thirteen companies in the offshore wind, oil and gas, and maritime sectors have launched a joint industry project – Coupled Analysis of Floating Wind Turbines – which will form the basis of recommended practice for the analysis of floating turbines. Companies contributing to the development of the recommended practice include Ramboll, Ideol, EDF, Maritime Research Institute Netherlands, STX Solutions Europe, Esteyco, Nautilus Floating Solutions, Dr Techn Olav Olsen, the National Renewable Energy Laboratory in the US, GICON, Glosten Associates, Atkins and Marintek in Norway. The recommended practice will build on experience from the application of offshore standard DNV-OS-J103 Design of Floating Wind Turbine Structures, which was published in 2013 and will focus on methods to fulfil the requirements set out in DNV-OS-J103. Since publication, DNV-OS-J103 has been widely used for the design of floating wind turbine structures.	http://www.owjonline.com/news/view,dnv-gl-plans-recommended-practice-for-new-floating-turbine-designs_44156.htm
• In September 2016, DNV GL has awarded the full project certificate for Innogy's 295 MW Nordsee Ost project in the German North Sea. The certification, carried out according to the German Federal Maritime and Hydrographic Agency's standard, covers all stages of the project development from design planning to commissioning, DNV GL said. Project certification of wind farms is mandatory in the country and Nordsee Ost is one of the first offshore wind farms to gain the award in Germany.	http://renews.biz/104368/nordsee-passes-dnv-gl-test/

57.4 Additional comments

None for this indicator

57.5 Recommendations

None for this indicator

58 Capital Availability - Bridge Equity (Construction) (% of total funding)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of equity	Capital availability	Capital Availability - Bridge Equity (Construction) (% of total funding)

58.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	Ahead of target	↑	Medium confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because evidence suggests that overall capital available for construction project funding is adequate, with no reports from engagement suggest a requirement for developers to source external bridging equity.

In CRMF 2015 this indicator was assessed as ‘on target’, noting that liquidity had increased significantly (when compared to CRMF 2014), well beyond the demands of the market, and that as such there was relatively little concern about equity becoming available in the construction phase. Particular attention was drawn to the entrance of new private finance participants and a general inertia towards more new entrants participating associated with the attractive returns available. A reluctance from anyone other than utilities or project developers to take on development phase risk is a trend described last year which continues and looks unlikely to change under a competitive CFD regime.

Timing was highlighted by engagement as an issue in this area. Specifically developers described a requirement to retain full equity stakes for longer than may be considered ideal, with time taken to conclude deals to bring in new partners and/or to reach full financial close as being challenging to align with CFD delivery milestones.

Outlook:

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator. The outlook in this area was generally positive. The impact of a potential shortage of funding for development phase activity and misalignment between CFD delivery milestones and FID processes unknown but not expected to be significantly detrimental to cost reduction between now and 2020.

58.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<20%	<20%	<20%	0%	0%
On target	20%	20%	20%	0%	0%
Behind target	20% - 40%	20% - 35%	20% - 30%	0% - 10%	0%
Missed target	>40%	>35%	>30%	>10%	0% - 10%

58.3 Evidence

58.3.1 Questionnaires

Category	Questionnaire response
Have you had to source bridge equity investment for projects taking FID in the current year? If so, roughly what % of total project cost did you have to bridge?	
[Finance]	N/A
[Finance]	No
[Developer]	Yes. 60%
[Developer]	No
Do you expect to have to source bridge equity investment for projects taking FID in the next 3 years? If so, roughly what % of total project cost do you expect to have to bridge?	
[Finance]	N/A
[Developer]	No

[Developer]	No
What drives your expectation for any future funding gaps?	
[Finance]	Significant development costs incurred for UK offshore wind projects prior to CFD auction stage with no certainty of auction success in my view results in a funding gap for the funding of development costs pre FID.
[Developer]	No expectation for future funding gaps

58.3.2 Interview

Category	Interview response
[Finance]	For both construction and operations, BNP are not aware of companies sourcing bridge equity to finance projects and are not expecting to see this in future. On the whole there is plenty of equity capital available for offshore wind projects.
[Finance]	OK, this indicator may be slightly outmoded, but what will drive future funding gaps? Development spend, will people really invest in a future tranche of development projects? This is a difficult problem, exacerbated by the size of next generation projects, the challenge is that there are only a very small number of (typically large) utilities who have sufficient balance sheets to finance development expenditure of future large sites. Those without cash are being seen to really struggle, and for next generation they are unlikely to be able to compete.

	Reality now is that there are 4 – 5 very large organisations who can shoulder development risk, but provided programme continues with a degree of visibility the chances of them losing out (CfD risk) is actually reducing, rationalisation has made it more certain, because fewer players and easier to determine what might happen in an auction round. Could envisage some future consolidation/JV for smaller players to allow them to have sufficient capital. We are not in a position where there is no DEVEX spend, and could be that 4 – 5 players could be an attractive number of developers to ensure robust competition in future. Size of projects is naturally limiting.

58.3.3 Market intelligence

Evidence	Source
None for this indicator	

58.4 Additional comments

None for this indicator

58.5 Recommendations

None for this indicator

59 Capital Availability - Bridge Equity (Operation) (% of total funding)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of equity	Capital availability	Capital Availability - Bridge Equity (Operation) (% of total funding)

59.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because in similarity to the previous indicator evidence suggests that there are no project developers describing a requirement to source external equity to bridge a funding gap.

Last year this indicator was assessed as ‘on target’ noting that there had been a notable improvement in the availability of equity for operational projects.

Participants described a significant move in the industry since the setting out of the milestone targets below. The fact that this indicator is comfortably ahead of target is actually a representation of a mode of operating that has moved so far in advance of that expected by historically set targets to suggest that the targets are almost irrelevant now.

Outlook:

A ‘high confidence’ was expressed by industry in the potential future outlook for this indicator. This is reflective of a greater degree of confidence in continued cost reduction through availability of equity for operational phase projects continuing to in greater supply than the demand to 2020.

59.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<10%	<10%	<10%	0%	0%
On target	10%	10%	10%	0%	0%
Behind target	10% - 40%	10% - 35%	10% - 20%	0% - 10%	0%
Missed target	>40%	>35%	>20%	>10%	0% - 10%

59.3 Evidence

59.3.1 Questionnaires

Category	Questionnaire response

Have you had to source bridge equity investment for projects currently in operation? If so, roughly what % of ownership did you have to bridge?	
[Finance]	N/A
[Developer]	No
Do you expect to have to source bridge equity investment for projects coming in to operation in the next 3 years? If so, roughly what % of ownership do you expect to have to bridge?	
[Finance]	N/A
[Developer]	No
What drives your expectation for any future funding gaps?	
[Finance]	N/A
[Developer]	No expectation for future funding gaps

59.3.2 Interview

Category	Interview response
None for this indicator	

59.3.3 Market intelligence

Evidence	Source
None for this indicator	

59.4 Additional comments

None for this indicator

59.5 Recommendations

None for this indicator

60Regulatory risk premium / asset beta (Asset beta)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of equity	Regulatory risk premium	Regulatory risk premium / asset beta (Asset beta)

60.1 Summary Analysis

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

Finding: On target

Marked as ‘on target’ in 2016 because there were mixed views on the current risk premium associated with offshore wind. On the one hand offshore wind represents a greater risk than an overall utility portfolio, primarily because of the association with a single technology. In contrast, offshore wind is considered less risky than other investments due to the ongoing support offered by government backed CFD underpinning successful projects.

Last year this indicator was also assessed as ‘on target’ noting that despite negative impacts on confidence resulting from uncertainty and policy changes, there was not clear evidence of an impact on risk premiums.

Outlook:

A ‘medium confidence’ was expressed by industry in the future outlook for progress in this indicator. This reflects a sentiment similar to that observed last year, regulatory risk remains as a factor with substantial remaining cost reduction potential, but expectations of an increase in certainty sufficient to reduce the asset beta before 2020 is not certain.

60.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<0.6	<0.5	<0.5	<0.5	<0.5
On target	0.6	0.5	0.5	0.5	0.5
Behind target	0.61 - 0.9	0.51 - 0.7	0.51 - 0.6	0.51 - 0.6	0.51 - 0.6
Missed target	>0.9	>0.7	>0.6	>0.6	>0.6

60.3 Evidence

60.3.1 Questionnaires

Category	Questionnaire response

Most recent analysis seen (from 2015) suggests asset betas in range 0.36 - 0.75 (average 0.59) for utilities operating in the UK. Does it make sense that offshore wind should be in line with the average?	
[Finance]	N/A
[Developer]	Generally yes – Similar exposures in some respect as with main Utility business including political/ regulatory environment. The CFD tariff model in the UK for offshore wind removes some power price risk that the utility companies are exposed to which could support a view towards a slightly lower beta.
Do you see asset beta changing in the next 3 years? (e.g. Increased/reduced clarity on CfD auctions; new technologies; improvements in and acceptance of operating strategies, etc.)	
[Finance]	N/A
[Developer]	No
What are the key factors influencing the regulatory risk premium?	
[Finance]	N/A
[Developer]	Future visibility of political & regulatory support for low carbon generation

60.3.2 Interview

Category	Interview response
[Finance]	Asset betas in the mainstream utility range of 0.6 are not expected on offshore wind projects, which are not likely to be in line with the average. BNP expect more risk in the asset beta of an offshore wind project because it is a single asset with technology concentration. Betas would be upward of 0.6. Improvements in technology, supply chain and project financing will reduce asset risk and betas for offshore wind projects and make projects more stable. Asset betas tend to be derived from listed companies which offshore wind projects are not, so BNP do not feel that this is a good indicator to assess risk. In qualitative terms, improvements in the indicators tracked by our CRMF study will contribute to making the sector less risky.
[Finance]	Did recent announcement change any perspective here? The announcement was great, was delayed but anticipated for some time. There remains uncertainty about what happens next. Having a longer term visibility/perspective of what will happen (e.g. LCF into future) and will next two rounds take place? Is there long term visibility of what the government wants to do with the sector in future? Probably not sufficient as industry had already assumed AR2 was ‘banked’ and going to happen eventually.

60.3.3 Market intelligence

Evidence	Source
None for this indicator	

60.4 Additional comments

None for this indicator

60.5 Recommendations

None for this indicator

61 Construction specific risk premium (P90 contract value multiple)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of equity	Construction risk premium	Construction specific risk premium (P90 contract value multiple)

61.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Behind target	Ahead of target	↑	High confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because sentiment expressed by participants suggested that progress in areas such as technology and market competition improvements have enabled construction projects to be delivered successfully, giving good confidence about a steady reduction in construction risk in future. Tempering the likely downward future trajectory is the ongoing evolution in the scope and type off offshore construction project that offshore wind will represent. It is likely that there will be a continuing increase in the distance from shore and MW scale of offshore wind farms, with many more ‘firsts’ yet to be achieved which will be inherently viewed as having greater risk associated. While there was no specific quantitative data available, interview respondents were comfortable that current multiples of P90/installation contract value were below the 2016 target of 1.8x.

Last year this indicator was assessed as ‘behind target’ noting that while there had not been a worsening of progress in reducing construction specific risk premium, rather that progress had been slower than anticipated previously. The entry of new additional sources of equity into construction and the building track record of projects that have been delivered successfully on time were described as both being anticipated to have a positive impact in the near future.

Outlook:

A ‘high confidence’ was expressed by finance sector respondents in the future outlook for this indicator. This reflects a sentiment that between now and 2020 there will continue to be on average a gradual downwards trend in construction specific risk premium. However the anticipated continuing evolution of sites and technology, as well as the influence of external factors could result in some fluctuation of this construction specific risk premium with the potential also to slight increases depending on the dynamics of each individual project. Overall, the effect is expected to be a net decrease in construction-specific risk premium, particularly taking into account improvements in risk allocation and contracting strategy.

61.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<1.8x	<1.7x	<1.7x	<1.7x	
On target	1.8x	1.7x	1.7x	1.7x	
Behind target	1.81 - 2.8x	1.71 - 2.5x	1.71 - 2.2x	1.71 - 2.0x	
Missed target	>2.8	>2.5	>2.2	>2.0	

61.3 Evidence

61.3.1 Questionnaires

Category	Questionnaire response
None for this indicator	

61.3.2 Interview

Category	Interview response
None for this indicator	

61.3.3 Market intelligence

Evidence	Source
None for this indicator	

61.4 Additional comments

None for this indicator

61.5 Recommendations

None for this indicator

62 Operations risk premium (P90 risk premium)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of equity	Operations risk premium	Operations risk premium (P90 risk premium)

62.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	On target		High confidence

Finding: On target

Marked as ‘on target’ in 2016 because evidence suggests that the in warranty (IW) portion of this target is being achieved and that the post warranty (PW) contingency % of contract value target has been comfortably exceeded. There are a variety of operations strategies employed on UK offshore projects, and diversity in approaches looks likely to continue. Some project owners favour in house or cost plus O&M arrangements, which can result in lower costs but greater contingency, with the finance community strongly preferring long term fixed price O&M contracts where greater value is placed on predictability than on achieving service at the lowest possible cost.

Last year this indicator was also assessed as ‘on target’ noting a similar diversity in approaches and a general expectation of steady reduction in contingencies in future.

In order to continue to drive down these contingencies, engagement suggested that as a greater base of long term operations experience is gained, the feeding of operational lessons learned into subsequent projects should be expected to reduce future project contingencies.

Outlook:

Engagement suggested that an average operational contingency of around 15% was expected by most to continue in the years to 2020. However, some reduction in the cost of this level of contingency may be achieved, as the underlying O&M budgets upon which this contingency is based are predicted by participants to decrease in future. Future projects are also expected to be able to reduce budgets and contingency by building on the ever growing foundation of O&M experience.

62.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	IW <9.3% / PW <31%	IW <9% / PW <30%	IW <8.5% / PW 28%	IW <7.5% / PW <25%	IW <7.5% / PW <20%
On target	IW 9.3% / PW 31%	IW 9% / PW 30%	IW 8.5% / PW 28%	IW 7.5% / PW 25%	IW 7.5% / PW 20%
Behind target	IW 9.31 - 14.3%; PW 31.01 - 45%	IW 9.01 - 12.5%; PW 30.01 - 45%	IW 8.51 - 10.5%; PW 28.01 - 40%	IW 7.51 - 9%; PW 25.01 - 35%	IW 7.51 - 9%; PW 25.01 - 35%
Missed target	IW >14.3% / PW >45%	IW >12.5% / PW >45%	IW >10.5% / PW >40%	IW >9.0% / PW >35%	IW >9.0% / PW >35%

62.3 Evidence

62.3.1 Questionnaires

Category	Questionnaire response
What P90/P50 contingency % on O&M budgets have you seen applied in current projects taking FID this year?	
[Finance]	N/A
[Developer]	The P50 contingency level has been considered to be 15% of the estimated OPEX budget overall.
What P90/P50 contingency % on O&M budgets do you expect to see applied in projects taking FID in the next 3 years?	
[Finance]	N/A
[Developer]	Same levels, but will depend on operational experience gathered by the company
What are the key drivers of your future outlook?	
[Finance]	N/A
[Developer]	Key drivers will be: operational experience inputting the design phase of the wind farms, evolution of market conditions, detailed engineering O&M focus on early stages of design reducing risks.

62.3.2 Interview

Category	Questionnaire response
[Finance]	Contingency percentages on O&M budgets have been dealt with in two ways: Cost plus type arrangements where contingency is added to the base budget to derive the DSCR after taking downside into account O&M budgets where the base budget already includes contractualised (effectively fixed) costs For lenders the preference is to have maximum certainty on expenditure (i.e. Scenario 2, above). Investors are more comfortable with having some cost risk (i.e. Scenario 1, above). The level of contingencies are likely to decrease in future as the sector matures – more projects, more certainty on costs and where variability exists, more access to the supply chain.
[Finance]	There is something of a trend for some parties to bring more expertise in operations in house, and seeking to take on more operations themselves. There is no evidence of a major strategic play by other big names seeking to do this more. Perhaps other respondents are seeing a better/closer view of this type of thing happening.

62.3.3 Market intelligence

Evidence	Source
None for this indicator	

62.4 Additional comments

None for this indicator

62.5 Recommendations

None for this indicator

63 Developer risk premium (% premium)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of equity	Developer risk premium	Developer risk premium (% premium)

63.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
On target	Ahead of target	↑	Medium confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there was overall no evidence suggesting that additional risks are being priced into the cost of equity. Overall the cost of equity has been described as reducing, driven by both increased competition between investors as a result of a maturing industry with a sufficient number of players but also by a lack of other similarly attractive investments offering the balance of risk to reward in other types of infrastructure investment. There was some indication from engagement that timing, in particular the risk of not being able to access the right finance at the right time was see as potentially slightly impacting progress in this area.

Last year this indicator was assessed as ‘on target’ noting that there was no evident shortage of equity or debt capital or major technical issues influencing risk. It was also suggested last year that the finance community were becoming more comfortable with the risks associated with technology innovations driving new sites, including primarily larger turbines.

Outlook:

A ‘medium confidence’ was expressed by industry in the future outlook for this indicator. The offshore wind industry is maturing, and an expected continuation of this trend looks likely to continue to lower the cost of equity on future projects. On the other hand, at present offshore wind is benefiting from a relative lack of similarly attractive competing investments, but improved returns in other markets could mean that funds are attracted away from offshore wind.

63.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<2.5%	<2.5%	<2.2%	<2.0%	<2.0%
On target	2.5%	2.5%	2.2%	2.0%	2.0%
Behind target	2.51 - 4.0%	2.51 - 3.5%	2.21 - 3.0%	2.01 - 2.3%	2.01 - 2.3%
Missed target	>4.0%	>3.5%	>3.0%	>2.3%	>2.3%

63.3 Evidence

63.3.1 Questionnaires

Category	Questionnaire response

In estimating cost of equity, what additional developer risk premium have you seen included for projects taking FID this year in order to capture all risks not covered by the specific (Installation and O&M) risk premiums and which cannot be diversified away. Examples include extreme downside risks, technology and refinancing risk.	
[Finance]	N/A
[Developer]	We typically analyse such risks and their probability of occurring as part of our risk management procedures which influence the amount of contingency and other mitigating measures we apply to the budget of a project.
In estimating cost of equity, what additional developer risk premium do you expect to see included for projects taking FID in the next 3 years in order to capture all risks not covered by the specific (Installation and O&M) risk premiums and which cannot be diversified away. Examples include extreme downside risks, technology and refinancing risk.	
[Finance]	N/A
[Developer]	No additional risk premium. Technology in offshore will continue to evolve in line with what we see now in the market. Refinancing risks considered low especially as market becomes a more established asset class.
What are the key drivers of your future outlook?	
[Developer]	See response above

63.3.2 Interview

Category	Interview response
[Finance]	In general [COMPANY] are seeing more downward pressure on the cost of equity. This has been a result of more competition for projects in the sector, more experience and the overall level of risk appearing to reduce in the sector. As a result we are seeing a decrease in overall risk premiums. In terms of future trends, this will depend on what happens in the macro economic climate. [COMPANY] are seeing money flowing into the infrastructure assets because interest rates on government bonds are at historically low levels. Whilst this continues there will be a continuing downward pressure on risk premiums. The offshore wind sector as a whole is performing well and driving lower risk premiums. A big disaster may drive the premiums up again.

63.3.3 Market intelligence

Evidence	Source
None for this indicator	

63.4 Additional comments

None for this indicator

63.5 Recommendations

None for this indicator

64 Gearing - construction (% of total funding)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of debt	Gearing	Gearing - construction (% of total funding)

64.1 Summary Analysis

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

Finding: Ahead of target

Marked as 'ahead of target' in 2016 because it was widely reported that gearing levels of 70 – 75% had been achieved on a variety of projects and this level of gearing was seem as commonplace. Debt finance was described as generally having been brought in at an earlier stage than in the past, with project finance coming in at FID in some cases. Gearing for some select areas (e.g. OFTO asset) has reached as high as 85%, although this is likely enabled by specific characteristics of the lending (e.g. shorter term).

Last year this indicator was also assessed as 'ahead of target' noting a trend for much higher levels of gearing being achieved than was envisaged by the indicator milestones.

Outlook:

A ‘high confidence’ was expressed by the industry in the future outlook for this indicator. This reflects a view that gearing of 75% represents a sustainable level, and that as such the 2020 target for this indicator has already been comfortably achieved.

It is thought unlikely that levels of gearing will increase further due to both the amount of debt that a project can afford, and also as a result of the increasing size of projects (and hence the number of lenders required) being expected to continue in one direction (e.g. projects will be larger) in future.

The level of debt financing has potential to be a significant cost reduction lever, but at present there does not appear to be a consistent approach or appetite across project developers to using project finance, suggesting that perhaps some further untapped cost reduction potential could remain.

64.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>20%	>40%	>40%	>40%	>40%
On target	20%	40%	40%	40%	40%
Behind target	0 - 20%	0 - 20%	20 - 30%	30 - 40%	30 - 40%
Missed target	<0%	<0%	<20%	<30%	<30%

64.3 Evidence

64.3.1 Questionnaires

Category	Questionnaire response
What % construction phase debt have you seen brought into projects taking FID this year?	
[Finance]	Typically seeing c. 70% construction debt in term loan and up to 85% debt in OFTO term loan, with one or two projects achieving 75% construction debt this year.
[Developer]	N/A – No external debt finance used.
What % construction phase debt do you expect to see brought into projects taking FID in the next 3 years?	
[Finance]	Up to 75% construction debt in term loans - I do not expect a significant shift from current levels.
[Developer]	We are unlikely to be using project finance debt for projects taking FID in the next 3 years.
What are the key drivers of your future outlook?	
[Finance]	A gearing level of 70/30, max 75/25 for offshore wind is reflective of the risk profile. Additionally the financing needs for offshore wind projects is significant given project sizes (each project typically seeks a debt raise of c. £1-2bn) and this debt

	requirement means that lending groups are sizeable (10-15 lenders). I don't expect sponsors to be successful in negotiating with large lender groups to accept aggressive gearing assumptions for offshore wind.
[Developer]	N/A
Have you had, or are you aware of any principal lending parties having had, problems with attracting lenders into a syndicate?	
[Finance]	Yes
[Developer]	No
If so, what is the extent of the issue (e.g. Indicative value of debt they are unable to syndicate)?	
[Developer]	N/A
How do you expect the situation to develop over the next 3 years? What will the key driving factors?	
[Finance]	Tight debt margins make the tickets unattractive
[Finance]	Unclear how situation will develop in near to medium term. Key driving factors will be pricing, evolution of other debt terms and conditions (more aggressive structures will make syndication processes challenging), evolution of lenders funding costs, success of Brexit negotiations and UK Government messaging regarding the prominence of offshore wind in the future UK energy mix.

[Developer]	Offshore wind is becoming a more attractive asset class to lenders, we expect this theme to continue over the next 3 years

64.3.2 Interview

Category	Interview response
[Finance]	Gearing up in the 70% range is being seen today for transactions. This is being seen at FID. There could be further increases in gearing as comfort with the technology increases. There is a major trend going against that due to the dramatic decreases in the CfD prices, which may reduce cover ratios that come out of projects. As margin gets tight with low strike prices, then cover ratios may reduce. Some lenders may be willing to accept that as it is a more established asset class but the fact that there is less cash flow to play with may restrain interests in gearing. Low strike prices today have benefited from higher gearing but this evidence shows there could be a tipping point. Gearing on construction of OFTO assets can be even higher, driven by the fact that the loan is for a shorter period and there is a well-established mechanism for valuing the asset and passing on the debt. Not likely to see 100% debt finance of OFTO construction, though theoretically possible at least if accompanied by some form of guarantees.
Have you had, or are you aware of any principal lending parties having had, problems with attracting lenders into a syndicate?	
[Finance]	In general it is taking a bit longer to syndicate offshore wind debt than people may have predicted 12 months ago because there are fewer new lenders entering the sector. Those who are, are taking longer to assess the risk in offshore wind than would have been expected. There is not a rush of additional capital into the sector. It is an asset where it is harder to sell debt to other banks than it would be in other infrastructure markets. The two factors keeping new lenders out of the market are that it is taking longer to get comfortable with offshore wind as an asset class than it is for equity investors, and some banks struggle with long repayment periods of debt that are a feature of offshore wind projects. This is likely to ease in

	future years but will happen more slowly than envisaged 12 months ago. Banks have come in much more slowly than expected. By 2020 it is a likely scenario that there will be a notable increase in the number of banks and lenders willing to look at offshore wind projects.
[Finance]	What used to have required 10 banks may now require 15, which can make things much more difficult. Debt in sterling is more of a challenge than debt in euros, where deals seem to be easier to place and there seems to be a more liquid syndication market. This could be interesting for future study/engagement. Margins are important only as relative in comparison to what can be achieved in other markets. Although looking low they are not necessarily a barrier as the CRMF methodology/targets may suggest. There has been a good recent track record of offshore wind projects being successfully delivered. Offshore wind is now a relatively mainstream early-mature infrastructure investment. If the general infrastructure market did start to return with better margins it could draw some money away from offshore wind, but actually offshore wind is relatively mature, banks are unlikely to get spooked by margins in offshore wind, even if other markets change, although accept that this type of consideration is quite nuanced.
How do you expect the situation to develop over the next 3 years? What will the key driving factors?	
[Developer]	The [Developer] answer and own experience and position is that projects so far have been balance sheet financed, for French projects because of the size it is likely that projects will go for project finance from construction. There is competition for investment with nuclear and other technologies, there may be a relatively low profile in the UK from [Developer] in offshore wind.

	Gaining finance is not about concern or risk associated with the technology itself, any constraint is more to do with competing with other places where the money could be invested.

64.3.3 Market intelligence

Evidence	Source
None for this indicator	

64.4 Additional comments

None for this indicator

64.5 Recommendations

None for this indicator

65 Gearing- operations (% of total funding)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of debt	Gearing	Gearing- operations (% of total funding)

65.1 Summary Analysis

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

Finding: Ahead of target

Marked as 'ahead of target' in 2016 because similarly to construction phase gearing operations phase gearing of up to 75% was described by participants.

Last year this indicator was also assessed as 'ahead of target' for similar reasons; the 2020 target appears to have already been comfortably exceeded.

Outlook:

A 'high confidence' was expressed by industry in the future outlook for this indicator, suggesting a sentiment that the current levels of gearing are considered to be sustainable and that targets described for years to 2020 have already been comfortable exceeded.

65.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	>40%	>40%	>40%	>40%	>40%
On target	40%	40%	40%	40%	40%
Behind target	0 - 40%	10 - 40%	20 - 40%	30 - 40%	30 - 40%
Missed target	<0%	<10%	<20%	<30%	<30%

65.3 Evidence

65.3.1 Questionnaires

Category	Questionnaire response
What % operating phase debt have you seen brought into projects currently operating?	
[Finance]	We have financed primarily greenfield assets this year, so difficult to be definitive. My sense is c. 75% operating phase debt, i.e. the top end of gearing levels for construction assets. Debt sizing is informed more by debt sizing cover ratios than

	gearing - gearing tends to be the output result, its debt sizing cover ratios that tend to constrain debt levels. For offshore wind, the market standard for debt sizing cover ratios is well understood and has not really changed.
[Developer]	No operating phase project debt in our current pipeline
What % operating phase debt do you expect to see brought into projects currently becoming operational in the next 3 years?	
[Finance]	See above response - I do not expect significant change from current levels because it tends to be debt sizing cover ratios which are the constraining factor.
[Developer]	This is not something we are actively seeking
What are the key drivers of your future outlook?	
[Finance]	Debt sizing cover ratios typically constrain debt rather than gearing levels and I do not see lenders accepting a deterioration in debt sizing cover ratios for offshore wind - perhaps at the margins, but no significant change.

65.3.2 Interview

Category	Questionnaire response
[Finance]	Most debt financing is a combined package for construction and operations, but are starting to see a partial refinancing for operations phase debt. There can be more gearing during operations phase projects driven by debt structuring. The

	refinancing can occur after a year or two of operations when parties are comfortable with the performance of the asset. Refinancing can be both getting better terms with the same lender and looking for other lending elsewhere. The preference is to talk to the existing lenders to see if they can accept a lower margin but there is no standard template for this (can be project specific).

65.3.3 Market intelligence

Evidence	Source
None for this indicator	

65.4 Additional comments

None for this indicator

65.5 Recommendations

None for this indicator

66 Construction debt margin (basis points margin, bps)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of debt	Change in debt margins	Construction debt margin (basis points margin, bps)

66.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target	⇨	High confidence

Finding: Ahead of target

Marked as 'ahead of target' in 2016 because evidence suggests that construction debt margins (in basis points) are commonly 200 – 225bp or 250 – 275 bp depending on whether considering operating or holding companies. Debt margins at these levels are comfortably ahead of the target for 2020, and as such enable this indicator to be assessed as 'ahead of target'.

Last year this indicator was also assessed as comfortably 'ahead of target'. It was noted that low debt margins had been driven lower as a result of progress in the industry such as entry of new banks, and support of EIB funding, but also by wider economic factors and a lack of competing transactions.

Outlook:

A ‘high confidence’ was expressed by industry in the future outlook for this indicator. Margins are expected to remain stable, there is little scope for further reduction but at the same time there are only limited pressures existing that could drive an increase. However, looking into the future, the anticipated size of future project funding requirements mean that future transactions are more likely to include a portion of more expensive debt.

Another important influence which has the potential to influence future performance in this indicator are developments in the wider economy. Specifically base rate movements or government bond yields and the general performance of the economy could both cause achievable construction debt margins to change in the coming years.

66.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<350	<350	<325	<325	<325
On target	350	350	325	325	325
Behind target	351 - 550	351 - 475	326 - 425	326 - 375	326 - 375
Missed target	>550	>475	>425	>375	>375

66.3 Evidence

66.3.1 Questionnaires

Category	Questionnaire response
What margin have you applied / seen on construction debt for projects taking FID this year?	
[Developer]	No construction debt taken on for our project achieving FID this year
What margin do you expect to apply / see on construction debt for projects taking FID in the next 3 years?	
[Developer]	Historic information suggests 300 bps.
What are the key drivers of your future outlook?	
[Developer]	N/A

66.3.2 Interview

Category	Questionnaire response
[Finance]	Margins on construction debt are tending to come down a little bit. Range of 210 to 225. During operations margins range of 200 to 240 for the long term elements of financing. For operations, considering a 15 year operation companies tend to start

	at the bottom end of the range then every 5 years it gets higher and higher. This helps sponsors to make decisions on refinancing at a lower rate as experience grows on a project. Over the next 3 years there may be a small amount of pressure on construction debt margins. It is likely to be minimal because there aren't a lot of banks entering the market that want to put downward pressure on pricing. The best way to get a low margin is to have a small project where not a large amount of finance from commercial banks has been required; as the amount of borrowing increases, owners are more likely to have to include some more expensive debt in the funding mix. Margins may increase where the holding company of a project has sought to source debt financing to fund their acquisition. In the case of financing a holding company, the lenders may be exposed to more risk, if the project gets in trouble there is no more revenue coming into the holding company to cover the debt. The lenders have security over the shares that holding company has in a project, so if something goes wrong with holding co, they seize control of the shareholding in the project and become X% shareholder in the project until they find another investor. If the debt is structured correctly the lender should get their money back but it is more risky than a conventional project financing structure, where the lender has a direct call on the project assets.

66.3.3 Market intelligence

Evidence	Source
None for this indicator	

66.4 Additional comments

None for this indicator

66.5 Recommendations

None for this indicator

67 Operations debt margin (basis points margin, bps)

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Cost of debt	Change in debt margins	Operations debt margin (basis points margin, bps)

67.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because evidence suggests that operations phase debt margins are in the range of 190 – 200bp, rising to 240bp towards the end of the loan tenor for operating companies and 240 – 250bp rising to 270 or 280bp towards the end of the loan tenor for holding companies. All of these values are lower than the ‘ahead of target’ milestone for this year.

Last year this indicator was also assessed as ‘ahead of target’ noting progress in market participants and also in a lack of other similarly attractive investment transactions.

Outlook:

A ‘high confidence’ was expressed by industry in the future outlook for this indicator. Similarly to the outlook for construction debt margin the future performance in this indicator is anticipated to generally remain ahead of target for at least the next few years. Caution should be maintained, in that a significant proportion of the benefit achieved here has been driven by the influence of economic factors from outside the offshore wind industry.

67.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<275	<250	<230	<215	<215
On target	275	250	230	215	215
Behind target	276 - 475	251 - 375	231 - 330	216 - 265	216 - 265
Missed target	>475	>375	>330	>265	>265

67.3 Evidence

67.3.1 Questionnaires

Category	Questionnaire response

What margin have you applied / seen on operations debt for projects currently in operation?	
[Developer]	N/A – No operations debt taken on
What margin do you expect to apply / see on operations debt for projects becoming operational in the next 3 years?	
[Developer]	Unknown – not in the market for this
What are the key drivers of your future outlook?	
[Developer]	N/A

67.3.2 Interview

Category	Questionnaire response
None for this indicator	

67.3.3 Market intelligence

Evidence	Source

None for this indicator	

67.4 Additional comments

None for this indicator

67.5 Recommendations

None for this indicator

68 Construction phase insurance

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Insurance	Insurance	Construction phase insurance

68.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	On target	↓	Medium confidence

Finding: On target

Marked as ‘on target’ in 2016 because evidence suggests that insurance premiums are in the region of £35 – 44k per MW for construction insurance. Key drivers of costs are described as including CAPEX value, turbine type, contractor experience, project schedule and value of deductible.

Last year this indicator was assessed as ‘ahead of target’ noting that there had been strong progress in reducing insurance premiums, and that a key driver of this was thought to have been an ongoing increase in the size of wind farms.

Outlook:

A ‘medium confidence’ was expressed by the industry in the future outlook for this indicator. This is reflective of an expectation that an increased demand from the growing worldwide offshore wind industry will likely be matched by new entrants continuing to be attracted to

this insurance market. Conservatism in the outlook for insurance is contributed by the fact that a significant contribution to the progress in insurance cost reduction in recent years has been delivered as a result of trends in the wider insurance market cycle. There also remains a sentiment that a major insurance loss on a single construction project could impact premiums on other projects, and as such cost reduction is dependent on the ongoing successful delivery of construction projects.

Without major loss events in either offshore wind or elsewhere in the insurance industry it is likely that the 2020 target for insurance costs will be achieved.

68.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<38,500	<38,000	<38,000	<38,000	<38,000
On target	38500	38000	38000	38000	38000
Behind target	38,501 - 48,500	38,001 - 48,000	38,001 - 43,000	38,001 - 41,000	38,001 - 41,000
Missed target	>48,500	>48,000	>43,000	>41,000	>41,000

68.3 Evidence

68.3.1 Questionnaires

Category	Questionnaire response
What range of construction insurance premiums have you applied / seen on projects taking FID this year? What have been the key factors driving increases or decreases from previous levels?	
[Insurance]	Lowest CAR rate was for [PROJECT]. Main driver of this was an increase in competition in the Insurance market, and an inability of many inexperienced Companies to accurately forecast the frequency and severity of claims on such risks. This inability to predict derives from the fact that claims in general are very limited in the early stages of a project, so results for insurers often look good until the latter stages when more damages typically occur. The variation in CAR rates was actually rather limited during the year, almost independent of risk features or coverage issues. This Again indicates an inexperience in the Insurance market. Cheap prices are of course of benefit to developers in the short term, although there is a medium term risk of cycles in the Insurance market and stability should also be valued.
[Finance]	Developers and insurance advisors are best placed to respond
[Finance]	Limited experience - sorry.
What range of operating insurance premiums do you expect to apply / see on projects becoming operational in the next 3 years?	

[Insurance]	It will vary based on the asset type and coverage requests.
[Finance]	Developers and insurance advisors are best placed to respond
[Finance]	as above
What are the key drivers of your future outlook?	
[Insurance]	Growth in the offshore Wind industry, countered by increased competition in the Insurance market and the Development of claims experience
[Finance]	Developers and insurance advisors are best placed to respond
[Developer]	Subject to status of the insurance market capacity, loss record and trends

68.3.2 Interview

Category	Interview response
What was the cost of insurance (in £k/MW) on your most recent construction project?	

[Insurance]	Insurance broker would be better placed to answer questions about cost of cover per MW who get full overview of market (i.e. Including [Insurance]'s competitors). Construction Phase Cover The offshore construction wording comes from oil and gas wording previous to the offshore wind industry. This structure is a widely accepted template across the industry.
[Insurance]	Cost of insurance depends on the type of insurance, there are many different types that not everyone buys. There are basic balance sheet products on the cheap end of the scale that don't provide revenue protection and just protect for construction risks. The cost of these products tends to be 0.5% to 0.7% on the CAPEX, depending on deductibles, where you are building the wind farm etc. This insurance does not include 3rd party liability coverage, which can be anything from £250k and £1m per project. If you choose revenue protection in the construction phase, this can be quite variable and will depend on what you are building and how you are building it and the project programme. Overall the insurance cost provided will depend on a number variables, not least the experience of the owner and their previous loss record, then who the contractors are, what they are building and when they are building it (the time of year). This will also be dependent on what the insurance market has been affected by across the sector that year e.g. hurricane losses and overall performance of the sector that year. There also generic insurance cyclical factors that are not influenced by offshore wind farms and can affect insurance costs. Ultimately it comes down to factors that are outside of the control of the owner/operator, the main one being insurance cycles that are influenced by factors outside of the offshore wind sector. Currently we are on the soft side of this scale as there have not been any recent major catastrophes that have affected the insurance market. The most dominant factor on insurance costs is the overall offshore wind sector performance. Offshore wind farm revenue protection insurance costs tend to be around 2 to 4% of the annual revenue generation. Construction phase insurance has been relatively flat, if not improving for a bit. As an industry, the loss ratio that insurers are working to is around 75-80% loss ratio, which is right on the money for a profitable business. Pricing for construction risk

	has been quite consistent and maybe come off by 10% over the last 12 months. This reduction is slowing down and the industry could be reaching the limits of profitability.
How do you expect this to change in the next few years?	
[Insurance]	Brokers like to gain some competitive advantage - broadening coverage in some areas and making tweaks. It is then insurers' duty to decide whether to accept/reject changes made. In construction wording, changes are modest because so many parties are involved (i.e. Owners, suppliers, contractors, lenders) it becomes difficult to get all parties to agree. [Insurance] works by applying a rate to the sum insured on the policy. Cost reduction is linked to both a lower overall project sum being insured and paying a lower rate on that sum. This combined impact has a faster effect on reducing insurance cost per MW. Rates have been reducing over time but he doesn't expect that construction rates can be reduced much further. However, he has seen competitors come out with rates that he doesn't see as sustainable. It takes time for claims experience to mature. If a construction premium is agreed today, insurers will not know for five years if that was a good decision. Insurance market is currently in a soft market cycle – plenty of companies bidding. To win business you largely need to accept terms and conditions. He sees the market staying competitive for the foreseeable future.
[Developer]	Have seen clearly more knowledgeable underwriters entering the market and a lowering of prices.

	[Developer] were expecting a fairly high price of insurance for [PROJECT] but have been pleasantly surprised with how low the price of insurance has been able to go, showing a significant cost reduction in construction phase insurance recently.
[Insurance]	There is more competition than ever in the insurance market for offshore wind with plenty of insurance capacity in the marketplace – there are 8 – 9 companies who are confident enough to provide insurance packages. However If the continuous business interruption issue with export cables is not resolved (at the moment this is ok but must make sure it does not escalate further) then this may have some impact on the availability of insurance cover in the marketplace. The increase in capacity is due to a maturing industry.

68.3.3 Market intelligence

Evidence	Source
None for this indicator	

68.4 Additional comments

None for this indicator

68.5 Recommendations

None for this indicator

69 Operations phase insurance

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	Insurance	Insurance	Operations phase insurance

69.1 Summary Analysis

2015 finding	2016 finding	Variance	Outlook
Ahead of target	Ahead of target		Medium confidence

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there is evidence to suggest that the cost of operations phase insurance had reduced to premiums in the range of £10 - £13,000/MW/year on operational projects, putting this indicator well ahead of target and suggesting that the 2020 target for cost reduction contributed by operational phase insurance has in some instances already been achieved.

Last year this indicator was also assessed as ‘ahead of target’ noting that the operational phase insurance is usually a significant cost for an operator and that the continued progress in lower than anticipated premiums would be contributing to a reduction in operating costs.

There is some depth to the picture of generally positive progress in average premiums reducing. The cost of operations phase insurance has probably reduced more quickly than for construction, but at the same time the premiums themselves are described as more volatile. Particular concerns were consistently raised around export infrastructure and an imbalance of risk exposure between wind farm and transmission operators. Ongoing issues with export infrastructure has been suggested as the primary driver for UK operators being

increasingly likely to purchase BI insurance, a cost which projects do not ordinarily chose to incur on European projects. The level of deductible was also described as varying significantly between organisations, which again can have significant influence on premiums. It is possible that some of the reduction in operations phase insurance premiums has been delivered as a result of operators taking larger deductibles and effectively deciding to take a greater degree of risk in house, expecting to react to minor incidents themselves.

Outlook:

A ‘medium confidence’ in the future outlook for this indicator was expressed by industry. There was a consistent feeling that while progress in premiums has been made, significant uncertainty or potential barriers to cost reduction exist and may manifest in future for operations phase insurance, with the most dominant single area being export cable failures. Improved data availability, analysis and operating track record can be expected to contribute to some ongoing cost reduction in operations phase insurance, although individual premiums are expected to remain volatile.

69.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<14,000	<14,000	<14,000	<13,000	<13,000
On target	14000	14000	14000	13000	13000
Behind target	14,001 - 19,000	14,001 - 17,000	14,001 - 15,500	13,001 - 14,000	13,001 - 14,000
Missed target	>19,000	>17,000	>15,500	>14,000	>14,000

69.3 Evidence

69.3.1 Questionnaires

Category	Questionnaire response
What range of operating insurance premiums have you applied / seen on projects currently in operation? What have been the key factors driving increases or decreases from previous levels?	
[Insurance]	Some premium drivers include - Insurance terms and conditions (deductibles, wording, whether BI cover is required or not) - risk features (asset types, known problems e.g. loss of fibres in export cables, quality of maintenance regime, business continuity plans, geographical location, availability of vessels) - claims experience - control over grid connection and (in)ability of OFTO to make quick repairs
[Finance]	Developers and insurance advisors are best placed to respond
[Finance]	Limited experience - sorry.
[Developer]	£10k – 13k /MW (considering a UK project, including IPT tax)

What range of operating insurance premiums do you expect to apply / see on projects becoming operational in the next 3 years?	
[Insurance]	Not possible to answer
[Finance]	Developers and insurance advisors are best placed to respond
[Developer]	Similar
What are the key drivers of your future outlook?	
[Insurance]	One big issue is how the OFTOs are able to Work with the windfarms, to ensure equitable sharing of risk.
[Finance]	Developers and insurance advisors are best placed to respond
[Developer]	Capex and Revenue estimates, Schedule, type of turbine, main contractors, level of deductibles, Country of project and applicable insurance taxes. Subject to status of the insurance market capacity, loss record and trends

69.3.2 Interview

Category	Interview response

What was the cost of insurance (in £k/MW) on your most recent operations project?	
[Insurance]	Insurance broker would be better placed to answer questions about cost of cover per MW who get full overview of market (i.e. Including [Insurance]'s competitors). Operational Phase cover Main beneficiary of cover is the project owner so they have more license to tweak cover as they want. Insurance brokers also have more license to take clauses from conventional power or other markets to give benefit to customer. Good in short term for customer to broaden cover – availability of broad cover seems to be increasing. However, if cover became too cheap, insurers would start leaving the market. On operational insurance – main component of cost is claim experience. Forecast for claims is based on historical performance. As it is a young industry with limited information, a safety margin is applied for uncertainty. In the future, premiums can more accurately reflect the industry risk. Operational insurance is generally quite profitable (but somewhat volatile). If there were to be a large claim on a large project, it could cost an insurer hundreds of millions and lead to higher premiums in the future. Operational insurance cost per MW varies hugely between projects based on deductibles. Some operators are taking deductibles up to €10m, others just €100,000. Wide range of risk appetite between operators. This makes it less easy to compare than construction phase insurance. Lenders often prefer certainty and may impose lower deductibles. Utilities (e.g. [Developer] or [Developer]) are more comfortable with the industry already.

[Developer]	Also see quite a reduction in the cost when renewing existing policies. Movements in the deductibles and clauses have become more competitive along with a shift in terms, generally by insurers seeking to make policies more attractive and remain competitive. Insurance market is probably now a lot more experienced, and also has many more underwriters keen to offer coverage of risk for offshore wind.
[Insurance]	During the operations phase, insurance cost can be upwards of 30-35% of the OPEX costs. Historically operations phase insurance has been a relatively benign class but in the last 12 months we have seen this change. Whilst it has been flat performance in construction leading to a more consistent pricing, for operations phase the performance has been dramatically reducing. Operational risk is now becoming much more of a concern meaning the rates are highly variable. Owners are buying a wide range of products, for example there are many with high deductibles in order to take out any minor losses. The biggest issues for operational risk have been around continuous business interruption, in particular the problems with export cables, which is a concern for insurers and is at the top of their risks. Unlike other property based business there has been a large take up of products with high continuous business interruption coverage – this is level of continuous business interruption coverage is fairly unique in the offshore wind sector. You could not buy this for an onshore power plant. If losses continue to come through then this will be recognised by insurers and will leave operators further exposed to OFTO risks. In terms of the lifetime of a project, when warranties expire operating insurance goes up as insurers have to pick up some of the warranty risk. The degree of increase depends on the experience of the operators and the performance of the wind farm, amongst other factors. The increase tends to be around 10% of a client's operating insurance cost. Beyond warranty [Insurance] are beginning to look for evidence of replacement scenarios for obsolete technology and consideration of availability of spare parts for old turbine models – what happens if you lose a turbine? [Insurance] are starting to consider different insurance requirements and values for different model at the end of operating life of an asset e.g. replanting, decommissioning. [Insurance] are starting to think at one point in a wind farms life do they start charging more for insurance.

	Do they charge more for an aging asset and at what point? 15 years plus is considered the risky period – asset is degrading an availability of spares for obsolete technology is reducing. [Insurance] feel we are now entering this cycle for a number of the installed assets which is going to increase insurance costs. Insurers will need convincing that an asset has reliable life left in it and the more data and evidence to prove that the better as this will take some convincing for insurers not to significantly increase the insurance costs.
How do you expect this to change in the next few years?	
[Insurance]	Industry currently works well; customers are getting what they want. In terms of cost reduction it is heading in the right direction. Insurance market is currently in a soft market cycle – plenty of companies bidding. To win business you largely need to accept terms and conditions. Sees the market staying competitive for the foreseeable future.
[Insurance]	There is more competition than ever in the insurance market for offshore wind with plenty of insurance capacity in the marketplace – there are 8 – 9 companies who are confident enough to provide insurance packages. However If the continuous business interruption issue with export cables is not resolved (at the moment this is ok but must make sure it does not escalate further) then this may have some impact on the availability of insurance cover in the marketplace. The increase in capacity is due to a maturing industry.

69.3.3 Market intelligence

Evidence	Source
None for this indicator	

69.4 Additional comments

None for this indicator

69.5 Recommendations

None for this indicator

70 OFTO TRS ratio to transfer value

CRMF workstream	Level 1 indicator	Level 2 indicator	Level 3 indicator
Finance	OFTO	OFTO TRS ratio to transfer value	OFTO TRS ratio to transfer value

70.1 Summary Analysis

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

Finding: Ahead of target

Marked as ‘ahead of target’ in 2016 because there is evidence that this metric, which has been devised to estimate the levels of competition and operational efficiency of OFTOs has seen steady reductions in recent years. Specifically this ratio was greater than 14% for licences granted in 2011 but has now reduced to around 7% for licences granted in 2016. Individual examples of a ratio lower than 7% also exist in 2015 and 2016, and as such it is reported that an ‘ahead of target’ cost reduction has been achieved in this area.

This is a new indicator for 2016, and as such no score from previous years exist with which to contrast the observed finding this year. However the rate of reduction does appear to have been significant, and is thought to be more aggressive than may have been expected had milestones been generated even 3 or 5 years ago.

Outlook:

A ‘high confidence’ was expressed by industry in the future outlook for this indicator. Competition in this sector is expected to continue to increase, with some remaining potential for returns to be driven even lower. Future potential progress in this area would be affected if there was a move to re-align the allocation of risk between operator and generator, although it is thought unlikely that this will have any impact in the years to 2020 as changes would take some time to materialise.

70.2 Milestone scorecard

Milestone scorecard	FID 2016	FID 2017	FID 2018	FID 2019	FID 2020
Ahead of target	<7.4%	<7.3%	<7.2%	<7.1%	<7%
On target	7.4%	7.3%	7.2%	7.1%	7.0%
Behind target	7.5% - 7.9%	7.4% - 7.8%	7.3% - 7.7%	7.2% - 7.6%	7.1% - 7.5%
Missed target	>7.9%	>7.8%	>7.7%	>7.6%	>7.5%

70.3 Evidence

70.3.1 Questionnaires

Category	Questionnaire response

Have you seen a shift in the relationship between the OFTO TRS to transfer value?	
[Developer]	Yes, the latest OFTO sale completed ([PROJECT]) has achieved the lowest TRS as a proportion of the transfer value (6.36%). Previous record belonged to [PROJECT] OFTO (6.88%) the sale of which was completed in February 2015.
[Developer]	Yes, it will naturally reduce as efficiencies increase
Do you believe there has been a reduction in costs as a result of increased levels of competition in Offshore transmission operators?	
[Developer]	Yes, the competition among OFTOs result in a reduction in their required TRS, and consequently a reduction of the local TNUoS that the Developers pay.
[Developer]	Yes – this is a contributing factor

70.3.2 Interview

Category	Questionnaire response
[Insurance]	[Insurance] are involved on both sides – insuring OFTOs themselves and project owners revenue loss (when export unavailable). He feels it is an issue that the project developer is totally reliant on OFTO for revenue. He feels OFTO's are not sufficiently incentivised to make quick repairs and take preventative action to reduce disruptions occurring. OFTOs rely heavily on insurers to pay for repairs and don't hold a fund for preventative measures. He feels OFTOs are struggling to perform to the right level.

	Looking forward, he predicts that if there are even a small number of failures (e.g. Three export cables failing, resulting in big revenue losses), he expects premiums to increase and restrictions in availability (?) which increase risk profile for owners. OFTOs operate with a very low risk profile. If owners are left with too high a risk that insurer's no longer want to take (due to history of taking big losses), they are left with a large risk that they have no control over. [Insurance] want to see conversation and collaboration between OFTO and owners to reach sensible agreements on paying for preventative maintenance or system condition monitoring, DTS systems, hot/cold spot, cable reburials, emergency response plans. Currently feels that OFTOs don't carry enough risk and there is not great collaboration. [Insurance] also work in Germany, Denmark and Belgium. In Germany and Denmark the grid operator takes a lot more risk for revenue loss from the wind farms which incentivises them to do better preventative maintenance. This is reflected in lower risk profiles for project owners (But may result in higher premiums for OFTO equivalents).
[Insurance]	There are concerns from some of the generator insurers about the lack of influence the generators have on the OFTOs. They are concerns that there are no contractual conditions or incentives to make the OFTOs improve maintenance approaches for export cables and expedite repairs in event of outages. For an insurer who is protecting a generator against continuous business interruption and the OFTO (who is not incentivised to maintain the asset) takes months to repair an export cable, this is a big risk to the insurer. The risk reward is not clear to the insurer and costs are felt heavily by the generator, impacting cost of energy.

70.3.3 Market intelligence

Evidence	Source

None for this indicator	

70.4 Additional comments

None for this indicator

70.5 Recommendations

None for this indicator

71 UK Content

71.1 Summary

The benefit of any sector to a countries overall industrial strategy will always be an important metric considered by Government and those providing support to an industry. UK offshore wind in particular has seen a steady increase in appetite to maximise UK economic benefit expressed by Government in line with the growth and maturation of the industry in recent years. It is now seen as a high priority.

Significant attention was paid by respondents and authors of this study to the dynamics of a drive for UK content in projects as part of CRMF 2016. As such these comments have been separated from the following ‘general comment’ section and are included below.

The contrast between cost reduction and UK content was often an emotive subject with a broad range of views expressed by participants in this study. In summary:

- There are clearly some areas of offshore wind projects where either specialist equipment, factories, ports or other infrastructure are essential and are simply not produced or available in the UK. In such cases there was generally consensus that to attempt to increase the UK content on these areas of a project would present a barrier to cost reduction, and that an absolute requirement could actually be a barrier to successful projects.
- In other areas there are some elements of a project where the locality of labour and supply is not only achievable but an obvious route to lower costs, making UK content the best route to cost reduction.
- Where there was not agreement was in the kind of content that exists in the middle ground between the two extremes described above, where it is not necessarily clear whether the UK economic benefit or lower costs represent the most beneficial way forward for the ultimate stakeholder; the energy using public.

Some participants clearly believed that UK content was fundamentally more expensive, but others did refute this, including with examples.

It is also important to represent another sentiment which was commonly expressed and reflect on the methodology for assessing UK content being critical to both perceived and actual success of this metric. If it is not measured in a transparent and methodical way it is likely that any perceived or actual target could actually drive undesirable behaviours.

71.2 Evidence

71.2.1 Questionnaires

Category	Questionnaire response
Do you have a policy or target for UK content in your supply chain? If so what is it?	
[WTG OEM]	Approx. 50% UK content over lifetime of project
[WTG OEM]	We are the largest investor into the UK supply chain with the £310m [PROJECT] creating 1000 new UK supply chain jobs. We are working closely with developers on Supply chain plans etc. and growing wherever possible UK content and suppliers.
[WTG OEM]	Business as usual to evaluate local sourcing UK content determined by competitiveness
[Developer]	No, this is driven on a project by project basis
[Developer]	We have a 50% UK content target. Measured in line with the standard industry methodology
What percentage of your product/service is made up of UK content currently?	

[WTG OEM]	Approx. 40%
[O&M]	15%
[Foundation]	15%
Designer / Survey	Also difficult to answer, most of our projects are run by collective of European [COMPANY] companies but I would say probably 25%.
[WTG OEM]	Confidentiality considerations
[Developer]	N/A
[Developer]	40% - 50%
Which elements of your supply chain do you believe will deliver higher UK content?	
[WTG OEM]	Blades, towers, O&M
[WTG OEM]	Blades currently. Greatest scope is in UK manufacture of foundations and possible tower investments
[WTG OEM]	Confidentiality considerations

[Developer]	Electrical system assets
[Developer]	OPEX related items (WTGs & BoP) WTG component manufacture Project resources Onshore installation & civils works Foundations fabrication works
What are the barriers to more UK content? e.g. cost, availability of skill or appropriate products, quality of service / products	
[WTG OEM]	Pipeline of UK projects for which we are nominated as the WTG supplier
[O&M]	Availability of skill and quality of service
[WTG OEM]	Moderate pipeline does nothing to encourage investment in new production capacity
[Foundation]	No input
[WTG OEM]	Competitiveness as determined by cost, quality, delivery.
[Developer]	Cost and availability of companies to provide the works

[Developer]	Other markets are ahead of the UK in some areas. The market for high and medium voltage subsea cable and installation are dominated by non UK contractors. There is serious competition in other areas such as fabrication within Europe with some non UK contractors at an advantage due to lower labour costs
What are the most compelling reasons to increase UK content?	
[WTG OEM]	Winning UK projects
[O&M]	Support the renewable commitment
[WTG OEM]	Hull factory will reduce cost - purpose built facility, on quay edge, close to critical mass of projects. Local content only makes sense if it can deliver at lower cost.
[Foundation]	Logistics costs
[WTG OEM]	Customer-driven, unless clear competitive advantage.
[Installation]	To enable the UK renewables market to stand on its own feet without foreign intervention in terms of equipment and skills.
[Developer]	Government requirements

[Developer]	Other markets are ahead of the UK in some areas. The market for high and medium voltage subsea cable and installation are dominated by non UK contractors. There is serious competition in other areas such as fabrication within Europe with some non UK contractors at an advantage due to lower labour costs Share the economic benefits of the projects in the markets that they serve.
What percentage of your customer base is in the UK?	
[O&M]	50%
[Foundation]	0%
Designer / Survey	Our customers are global but we do work with some UK based developers and tier one contractors but mainly they are based overseas. percentage wise it is probably 20-25%
What percentage of your turn over is offshore wind?	
[O&M]	100%
[Foundation]	10%

Designer / Survey	Difficult question to answer, probably 7.5- 10% of the [COMPANY] group turnover
Do you have direct oversea competition?	
Designer / Survey	Yes and also from UK.
What would improve your competitiveness?	
Designer / Survey	We aim to offer better value for money, and aim to lower the client's risk profile. Unfortunately most client in OWF make their decisions in procurement where some of the added value of using [COMPANY] is not appreciated.

71.2.2 Interview

Category	Interview response
[Installation]	Despite requirements for UK projects to demonstrate UK content in the supply chain, costs remain more important for developers. Day rates for [Installation] are the same of UK, German, Dutch etc. projects, however because the UK has a UK content element, [Installation] make large efforts to ensure they remain competitive in the UK market, as this may be the next decision point after price for selecting a supplier.

[WTG OEM]	[WTG OEM] have a policy for UK content, are being involved in all discussions, have been chairing supply chain group under OWPB. [WTG OEM] are focussing on their suppliers to look for more from the UK, and at the same time are under pressure to demonstrate their increasing UK content to their customers. [WTG OEM] recognise that local content is a critical requirement for government and general population, and feel that they have made the biggest single step of anybody by investing in Hull. They are making a big effort to make sure that their suppliers are UK and in finding new UK suppliers where possible. Have been very involved in supply chain process with those bidding into CfD to demonstrate what UK content they have. The message from developers is that they want to drive up UK content, but not at a cost premium, this may change in future, they might get squeezed to ensure that they support UK content even when it may not be the lowest cost solution but up to now cost has been the deciding factor for their customers. Almost don't have to work too hard at O&M/service local content, as it is almost taken as a given that this will happen. Big opportunities for stimulation of supply chain growth with big wins are in big ticket capex – good opportunity to for example do fabrication and foundations in the UK. [WTG OEM] are able to invest in factory when the demand is known to be there and there is unserved capacity. The industry as it exists can build the pipeline expected easily, so further such investments based on a relatively conservative build pipeline look unlikely.
[O&M]	[O&M] have heard from a client that when reviewing tenders they consider price then safety then local content. This may differ from what the UK Government perceive to be the case. [O&M] believe that local content obligations do not give UK companies that many advantages over EU suppliers. It can be easy for EU companies to get around UK content by setting up a satellite office in the UK.

[WTG OEM]	A lot of the O&M provision and service/support helps to bring UK content up. [WTG OEM] see the unstated aim from UK government seeking to see 50% UK content. As a key OEM [WTG OEM] see that it is important to demonstrate that in blades or towers for example they are making efforts of increase or contribute significant UK economic benefit. These systems are some of the big ticket items which are being sourced in the UK. Foundations is not in the [WTG OEM] scope, but for example on the [PROJECT] project all foundations came from [COMPANY], so actually a very early project without pressure to do so achieved something like 47% UK content. This shows that it can be done. Something which has gotten press recently and could be a concern was [PROJECT] choosing to award substantial amount of their foundations out of the UK. Although important to acknowledge that there are probably several reasons behind this, could be political or technical or a combination. The industry expects to go below £100/MWh in next CfD round, this now looks pretty certain.
[Developer]	We are working to develop sustainable, credible competition in the local supply chain.
[Foundation]	The amount of UK content that goes into [Foundation] fabrication projects is something which the developers controls. Developers will always look for the best case on local content and this may not necessarily be in foundations. If they cannot find low UK content costs in foundations they will look to find it in other areas of the wind farm development packages e.g. turbines and cables. Some are taking less of the local content percentage in foundations packages, potentially because they can find it cheaper in other packages. Politics is a driver for local content but developers are increasingly pressed to get the best price when they win competitive auction rounds.

	A UK based fabrication company is producing foundation elements and rolling steel but all the secondary components and materials they incorporate in their products are imported. The UK content is primarily the cost of labour and they are winning work because they have a UK footprint. However, now that they have won work there does not seem to be any push to base more of their fabrication on materials from the UK supply chain. There are some grey areas on the use of local UK content When going through the tender process developers push hard on local content, as requested by the government. However, commercial decisions still dominate, especially if developers have an overseas board.
[Electrical]	Developers make a point of not insisting on offers having UK content, cost is king but they do like to see UK supply being used where it can be. For example GIS switchgear cannot be bought in the UK from a UK manufacturer, and there is not a business case in opening a factory just to serve offshore wind in the UK, this and other commodity type components are never going to offer UK content to any offshore wind project, regardless of who you buy it from. A recent [Electrical] project has 63% of UK project as UK content, driven by small suppliers and main subcontractors doing much of the associated work alongside engineering and PM function in the UK Another is 23%, where labour is the main UK component so it can vary.

	As a business [Electrical] are tracking local content because they are regularly asked the question by developers. All of the numbers are driven by where things are being manufactured. 2/3rds is a typical value of UK content for [Electrical] grid projects when the scope is a turnkey substation.
[O&M]	Pressures have increased on developers to increase local UK content and there lots more discussions about it ongoing. Local content can be important for operations and logistics e.g. having access to a local supply chain to service a wind farm. Despite this price still dominates. Experience is also important. The main attraction for developers would be to have well experienced, local content that can compete on price. Unfortunately small UK companies don't often have this. Another important attribute for a company is resilience i.e. the company is not only exposed to one market. Competing European supply chain companies are often exposed to more markets than just offshore wind and therefore have more resilience (less risky).

71.2.3 Market intelligence

Evidence	Source
None for this indicator	

71.3 Additional comments

None for this indicator

71.4 Recommendations

None for this indicator

72 General comments

72.1 Summary

During industry engagement, participants were given an opportunity to provide additional comments which they felt were relevant to describing cost reduction from their perspective. These comments are provided in this section.

72.1.1 Interview

Category	Interview response
[Insurance]	To reiterate – there seems to be inherent problem (throughout Europe) in export cables that needs to be looked at. The most frequent claims are due to gearbox failures, bearing failure, blade issues - but these are small scale claims that cause no special concerns. Repair time varies by project, from a few weeks to months. He is aware of the potential for large claims due to substation failures but hasn't experienced it yet.
[WTG OEM]	Recent journalist question is indicative of a general issue, a lack of understanding of what is going on with levelised cost of offshore wind. Lots of confusion about what LCOE actually is and how there can be justification of such a range of project costs. [PROJECT] has a very low price, doesn't include development or grid cost. It is also not an indexed cost, so actually extremely low when considered in comparison to UK projects which receive index linked support. Expect that next auction could really address the issue of LCOE by moving down dramatically and could make offshore wind competitive with other forms of new energy. Many parties have been working hard and have optimised every aspect of the industry, which has rapidly reduced costs.

	Brexit uncertainty and potential for energy process to increase in future.
[O&M]	There is still a big difference between OEMs and Owner/Operators around motivations for O&M. Operators are much more interested in AEP so are more engaged in improving O&M out of warranty, Blade leading edge erosion is a massive challenge where the industry have underestimated the issue and the consequences for blade repair practicalities and costs. The industry is now having to play catch up to find solutions whilst maintaining the damage.
[WTG OEM]	There must come a point where cost reduction will no longer be sustainable. The industry and supply chain may feel that we could be quite near to reaching a plateau where supply chain are not incentivised to innovate or invest because they do not see that they will get a decent return and their margins are increasingly become squeezed.
[WTG OEM]	CRMF suggests that size of turbines has driven a lot of the cost reductions so far, should not lose sight of innovations and improvements in other areas such as foundations, or electrical etc. Why are we not seeing more deployment of better projects and cost reductions there? Customers are expecting turbine OEMs to be in consortiums so they are starting to work closely on some bids with foundation contractors, not expecting to start doing work independently or develop their own technology outside of turbine supply only. Could be more UK government support proactively floating offshore wind? Good opportunity here for things to happen if it is supported.
[WTG OEM]	How do you compare far from shore projects with near shore projects, this is a challenge for the CFD system, how to compare like with like, operating costs will influence and vary significantly?

	There is a need to find a proper and good way to encourage innovation in the supply chain. If government want cost reduction they should be looking at new and different ways to encourage developers and their suppliers to find and fund innovation. Some concern also about Brexit implications, particularly in funding of research programmes for example such as EU FP7. If all costs are being squeezed, it will be harder to find cost reduction, not easier, as returns that were once expected may not actually be delivered.
[Foundation]	The industry used to primarily look at how to reduce LCOE through CAPEX and perhaps couldn't get any significant cost out from turbine OEM, but it was ok as everyone had a business case. Are now seeing s complete change in mind-set of industry, revenue stream is much different now, and so need to go in with a really aggressive bid, and so CAPEX remains as a big question, probably not a lot more that can be done with conventional BOP systems, this is driving interest in trying other things. Innovation willingness has increased because of commercial pressures. Sweet spot in market as only place where foundation is available for tendering into projects, no other sufficiently mature competitors. Need to make sure that there is a healthy cost reduction, and that cost reductions also have an eye on the sustainability of the industry.
[Electrical]	Electrical equipment is always going to be the same, fairly fixed pricing, the key opportunity to reduce costs is in topside design, fabrication and installation. [WTG OEM] suggest 30-40% reduction in cost to go back to a containerised solution, which seems plausible.

	66 kV and increasing export cable voltages are keys that need to be looked at to reduce costs, current state of the art in transmission could improve in cables and allow substations to offer more capability/cost reduction.
[Finance]	The largest technology risk is the speed at which new models are coming onto the market. These turbine models are being financed at a much earlier stage than expected for the development of the technology so it remains to be seen what the commercial risks may be.
[Finance]	General points, recalibration of CRMF should be considered, market has moved so far from scope of original indicators now in some areas, is there a way to reflect in reporting how things have changed so much since the indicators laid out in the past? Many of the finance indicators have easily achieved their targets. Question on gearing – has already been easily exceeded. We have moved so far beyond this. Some outlooks are difficult to score as there are various recipes used by developers and there are many which have shades of grey. OREC acknowledge that it is important to reflect in the detailed and summary CRMF reports the extent of achievement relative to original indicators.

72.2 Additional comments

None for this indicator

72.3 Recommendations

None for this indicator

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