Statoil

Budget Period 1 Summary Report

Hywind Maine Project

DE-FOA-0000401: U.S. Offshore Wind: Advanced Technology Demonstration Projects

February 28, 2014

Public Report

Contents

1 Introduction 4
1.1 Scope of work...4
1.2 Objectives..4
1.3 Overview of Hywind Maine activities..5
2 Accomplishments for the project 7
2.1 Design..7
2.1.1 General 7
2.1.2 Assessment and documentation of Meteorological conditions 7
2.1.3 Assessment of Bathymetric and Geotechnical conditions (See also Section 3.1.2 below)......................7
2.1.4 The Project Design Basis Document 8
2.1.5 Wind resource and energy assessment 8
2.1.6 Overall park layout..9
2.1.7 Substructure design, WTG system solution, including tower 9
2.1.8 Mooring solution including layout and anchoring...10
2.1.9 Inter-array cable solution 10
2.1.10 Offshore export cable (static) solution including route to landfall 10
2.1.11 Onshore export cable solution (including landfall & route) 10
2.1.12 Supply chain and market assessments..11
2.2 NREL Collaboration 11
2.2.1 NREL Work Packages (WP)..11
2.3 Construction and Installation Activities 14
2.3.1 Fabrication, transport, storage and staging site of the WTG and tower 15
2.3.2 Substructure Fabrication, Yard Assembly and transport 15
2.3.3 Assembly...16

2.4 Operation and Maintenance 18

2.5 Environmental and Permitting Process 18

2.5.1 Project site planning and studies 18

2.5.2 Environmental and design parameter studies 19

2.5.3 Agency engagement and stakeholder management 19

2.6 Grid Interconnection 20

2.6.1 Status grid Interconnection 20

2.6.2 Power Offtake agreement 21

3 Progress regarding innovations leading to potential reductions in LCOE 22

3.1 Innovations related to the Hywind concept 22

3.2 Design optimization and up-scaling 23

3.3 Wake effects for floating WTG 23

3.4 Substructure Innovations 24

3.5 Assembly and installation innovation 24

3.6 Demonstration of new technology 24

Figure 1: Post-survey Location Map 8

Figure 2: Main dimensions of Hywind Maine (right) compared with Hywind Demo (left) 9

Figure 3: Illustration of mooring configuration 10

Figure 4 Preliminary offshore export cable route 11

Figure 5: Illustration of inshore assembly .... **Error! Bookmark not defined.**

Figure 7: LCOE Breakdown by Cost Category (source NREL) .... **Error! Bookmark not defined.**

1 Introduction

1.1 Scope of work

In accordance with the Statement of Project Objectives (SOPO) agreed to between the Department of Energy (“DOE”) and Statoil for the Hywind Maine project, Statoil hereby submits a public version of the Summary Report which includes; accomplishments for the project including summaries of the other submitted reports (see Section 1.2-2); progress regarding innovations leading to potential reductions in the Cost of Energy (see Section 3).

1.2 Objectives

The Hywind Demo project, the world’s first full-scale 2.3 megawatts (MW) floating wind turbine, installed at a water depth of 200 meter (m), 10 kilometer (km) off the coast of Norway, has proven that the Hywind floating substructure is a suitable platform for conventional multi- MW turbines. A principal goal of the Hywind Maine Project was to leverage that experience, both to demonstrate the commercial feasibility of the technology and to further develop and optimize the technology all in order to bring the costs down in a larger scale development.

With the Hywind Maine Project, Statoil planned to deploy four turbines of 3 MW in approximately 140 meters water depth. While the Project would have positive effects on several levels and was expected to be a showcase for a worldwide market, the most prominent objectives of the park were:

- Technical innovation and validation: Utilize the Hywind Demo construction experience and operational performance data to develop and demonstrate a more optimized and cost efficient design, with a larger turbine and a lighter substructure. Furthermore, the project will study the effect of wake and turbulence on the floater motions for floating turbines in a park with multiple units, and demonstrate the concept and the motion controller for use in a park configuration. The Project design is being developed by use of a sophisticated coupled dynamic model, scalable to larger turbine units. A critical part of the concept is the Statoil-developed pitch regulator, which has already been tested on Hywind Demo and will be adapted to the new design. Thus, the Hywind Maine Project will monitor the continued success of this advanced pitch regulator in a new and different setting.

- Risk reduction for large park development: The Hywind Maine Project will advance the general base of knowledge for offshore floating wind, thereby reducing the risk for future large scale wind park development.

- Cost reduction and market acceptance: Obtain validation of construction, installation and operating costs based on a multiple-turbine park. Demonstrating scalability of costs is viewed as a key step to building credibility in the market for the commercialization of floating wind parks. The objective is to demonstrate the path for Statoil and other developers to achieve cost reduction and full-scale commercial viability.

- Building a domestic industry: Strengthen the U.S. supply chain’s ability to deliver according to industry expectations, combining Statoil’s offshore experience with U.S. domestic knowledge. A mature, competitive supply chain is crucial to the ultimate cost competitiveness of offshore wind. Further, U.S.

offshore wind industry expertise will be advanced by publishing key results from the Project in collaboration with a renowned U.S. research institution.

- Successful navigation in a heretofore untested permitting paradigm: For the Hywind Maine Project, Statoil filed an unsolicited request for a 20-year offshore commercial lease with the Bureau of Offshore Energy Management (BOEM). Statoil anticipated a federal/state regulatory approvals process commensurate with the Project's scale that would enable operations to commence in 2017 or earlier. Drawing from Statoil's experience with offshore wind developments in Europe, the Project will advance the general base of knowledge in the U.S., and thereby help improve the effectiveness of the nascent U.S. regulatory approval processes. Validating and helping advance a manageable permitting process is important to build industry confidence.

- Public acceptance of offshore wind turbines: As one of Statoil's core values, and building on experience from similar projects, Statoil set out to focus on openness and involvement of stakeholders in key processes, to help generate public acceptance of offshore wind in the U.S.

- Environmental feasibility: The Hywind concept is, with its small seabed footprint and no need for piling operations, a gentle solution in marine environments. An important output from the project will be to validate this statement through real-life testing and in dialogue with key state and federal agencies to build confidence in moving to a large-scale deployment.

1.3 Overview of Hywind Maine activities

Drawing on its experience in offshore oil and gas production, Statoil has spent over 10 years maturing the Hywind concept - a new technology platform for floating wind turbines. In 2009, Statoil deployed the Hywind Demo, and has studied its performance in the intervening years. The company has determined that the next critical step towards full-scale commercial viability and market acceptance is the build-out of a floating wind farm with a few (4-5) turbines, where cost reductions can be demonstrated and park effects studied. Statoil has assessed several locations for such a wind farm, e.g. in Scotland and Maine.

In 2010 Statoil started early phase work in Maine to develop a pilot park consisting of 4 turbines. Maine was chosen due to strong local support for floating wind, good wind resources, and a potentially capable supply chain.

In May 2011, Statoil responded to a Request for Proposals for Long-term Contracts for Deep-Water Offshore Wind Energy Pilot Projects in Maine and later that year started negotiations with the Maine Public Utility Commission "'MPUC" or "Commission") Staff to develop a term sheet, which would be the basis for a long term power purchase agreement ("PPA").

In 2011, Statoil also submitted an unsolicited, outer continental shelf ("OCS") lease application to the Bureau of Ocean Energy Management ("BOEM"), and in 2012 BOEM determined that there was no competitive interest for the requested lease area. On this basis, Statoil initiated Environmental Impact Assessment ("EIA") surveys, prepared for the state and federal permitting process, developed design studies, supply chain studies, and initiated the grid interconnection application process. In May 2012 Statoil applied for DOE support under the Advanced Technology Demonstration projects program and was one of seven projects which was granted 4 MUSD in the first Budget Period (BP1).

On January 24, 2013 the MPUC approved the PPA term sheet and Statoil entered into negotiations with the MPUC Staff and Central Maine Power ("CMP") to develop the fully termed PPA. During the summer of 2013, as PPA negotiations were progressing, the Maine legislature approved an amendment to the Ocean Energy Act (OEA), which required the Commission to hold a second round of competitive solicitations for the RFP Statoil competed for back in 2011

In July, as a result of the procedural and commercial uncertainty created by the amendment to the OEA, Statoil put the Maine specific activities on hold until the risk picture for the Project could be fully analyzed. In October, as part of the company's internal project development process, a decision was made to terminate the Maine project, and instead focus Statoil's efforts on one single, demonstration park in Scotland. The Scotland project is a floating offshore pilot wind farm located at Buchan Deep, approximately 20 km east of Peterhead on the east coast of Scotland. Subsequently, Statoil wound down all of the Project activities which included a withdrawal from the RFP, grid interconnection and OCS lease application processes.

Despite the termination of the Project, and after consultation with NREL and the DOE, the parties determined that additional value could be derived by continuing the design basis work started in BP1, with a revised scope of work. This work has general applicability to both the Hywind Concept and to the development of the US offshore wind industry.

Although the project in Maine will not move forward, much value was gained through the BP1 work package. Advanced modeling related to the design basis, which will have applicability beyond the Maine project, was completed. In addition, initial supply chain analyses were conducted, which will help assist with development of updated cost of energy models. Geophysical and various environmental surveys were also conducted, the results of which Statoil has committed to share publicly, and which will help build a database of information that future developers may be able to access. Finally, Statoil gained a greater understanding of the US offshore wind industry and related markets, which will assist the company as it looks for full-scale, commercial opportunities.

2 Accomplishments for the project

2.1 Design

2.1.1 General

The Hywind Maine design was developed based on the use of four traditional, three-bladed upwind wind turbine generators ("WTG") mounted on ballasted cylindrical steel substructures moored to the seabed by mooring lines and anchors (the "Hywind concept"). The Hywind Maine concept was developed for turbines with a nameplate capacity of 3MW, giving a total park capacity of 12MW. These turbines would be connected together in a chain by infield cables with a subsea export cable to shore. A substation for grid connection and potential landfall locations for the export cable were identified close to Boothbay Harbor.

Sections 2.1 and 2.2 provide an overview of preliminary engineering development/design activities that were accomplished prior to the Project being terminated in October 2013.

The data provided below are primarily associated with the 'Base Case' Hywind Maine design.

2.1.2 Assessment and documentation of Meteorological conditions

Statoil produced a Metocean Design Basis specific to the proposed Hywind Maine location.. Wave data were obtained from the European Centre for Medium-Range Weather Forecast (ECMWF) hindcast archive. In order to validate the ECMWF hindcast data, a comparison with the E01 buoy and ECMWF was performed. Wind data were obtained from a hindcast model operated by StormGeo. The data are based on fine scale wind modelling with the Weather Research and Forecasting (WRF) model and has a horizontal resolution of 2 km.

2.1.3 Assessment of Bathymetric and Geotechnical conditions (See also Section 3.1.2 below)

Geophysical surveys for the lease site and offshore cable route were undertaken during BP1. In addition, a bathymetry survey was performed for the tow route. Due to a hold placed on Maine-specific activities during the summer, the scope was reduced for the latter parts of the survey. However, the results still provide important data related to the lease site, cable routing and tow route. Significant areas of bedrock were identified during the surveys, which could have an impact on the placement of the mooring system and also the route selected for the offshore export cable. The North Eastern lease area appears to be most favorable in relation to soil conditions for anchoring. The cable routing will have some areas of solid bedrock.

See Figure 1 for the post-survey location map.

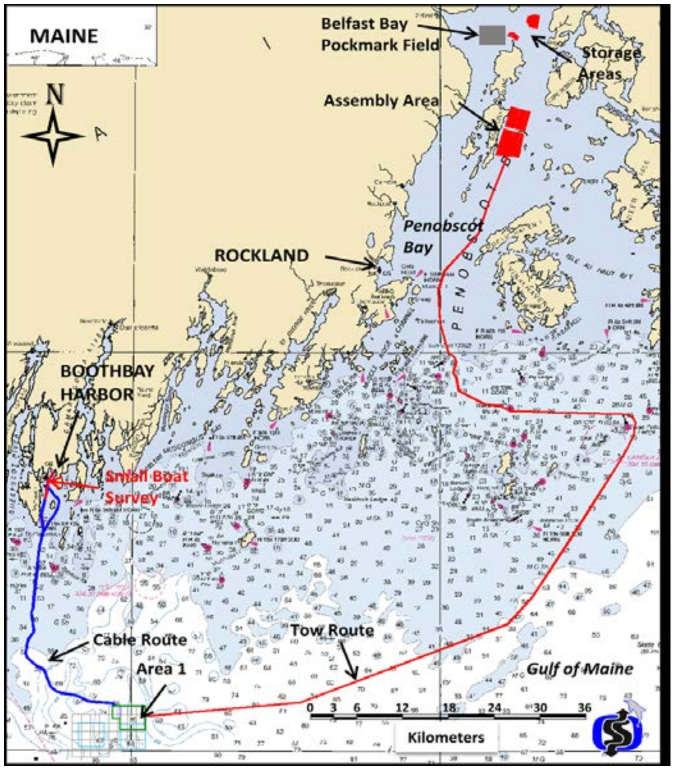

Figure 1: Post-survey Location Map

2.1.4 The Project Design Basis Document

During BP1, Statoil prepared the Design Basis for the Hywind Maine Project, stating the design premises and principles for developing the Hywind Maine pilot park project. A list of Technical and Operational Requirements and Guidelines (TORG), was also developed, comprising the assessment of technical and operational requirements, standards and guidelines to be applied during the concept phase of the Hywind Maine project development.

2.1.5 Wind resource and energy assessment

A wind resource assessment for the proposed Hywind Maine site was undertaken based on a 10 year WRF model hindcast data set. The yearly mean wind speed at the site varies between 9.27 m/s and 9.36 m/s (at 70m above sea level). The main wind direction is from the south west, however seasonal differences are very pronounced. Overall, westerly winds are dominant.

Two different layout types were evaluated: one with a more compact (minimum 6D) and one with a wider (minimum 7D) turbine spacing. The best and worst case locations with respect to production were identified. Production estimates were calculated for the best and worst case site as well as for a base case site, which is a compromise between the best and worst case. The net Annual Energy Production (AEP) varies with 0.7 GWh/year or 0.7 % (percent points) in capacity factor.

In the worst case, a yearly net production (P50) of 46.2 GWh/year is achieved, and in the best case, the yearly net production is estimated to 46.9 GWh/year. The base case scenario ranges in the middle with a P50 annual energy production of 46.5 GWh/year with an uncertainty of approximately ±18 % on the 10-year P50 assuming a normal distribution of uncertainty values.

2.1.6 Overall park layout

Based upon considerations related to: (1) relevant stakeholders (e.g. fishermen); and (2), environmental and engineering (e.g. geotechnical) criteria/constraints, a preliminary layout of the Hywind Maine Park was established. A description of the 'narrowing down process' (micro-siting) undertaken by the Project is included in a Site Characterization Report.

2.1.7 Substructure design, WTG system solution, including tower

Initial substructure sizing work and material selection criteria, was carried out allowing for optimization iterations. Verification analyses were carried out using detailed, coupled, dynamic simulations. The structural design work emphasized reducing steel weight, reducing stress concentration, fabrication cost/simplification, and fabrication methods at shipyards. However, at the time the project was terminated (Oct. 2013), the structural design was considered to be preliminary and further optimization of the design (e.g. in order to reduce overall costs) would have been undertaken.

Design scantlings of the lower section of the substructure are governed by the Ultimate Limit State (ULS) condition; i.e. extreme external pressure and bending moment. The design of the upper section is governed by the Fatigue Limit State (FLS) condition; i.e. long term bending moment history.

Stability and wanted dynamic characteristics of the unit is achieved by using heavy ballast at the bottom of the substructure. Intact stability is checked against requirements given in the Det Norske Veritas (DNV) standard for floating wind turbines (DNV-OS-J103). The main dimensions for the concept are illustrated in Figure 2.

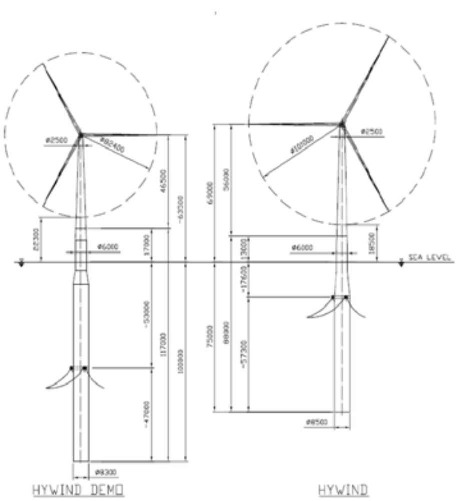

Figure 2: Main dimensions of Hywind Maine (right) compared with Hywind Demo (left)

2.1.8 Mooring solution including layout and anchoring

Mooring system analyses were undertaken for varying water depths and chain diameters. The selected mooring system is a catenary mooring system with three mooring lines, connected to the substructure by use of bridles (to increase the yaw stiffness) as shown in figure 3 While the use of drag embedment anchors is the base case, other anchor alternatives would have been evaluated in later BPs, when more detailed soil data became available. (See also Section Section 2.2.1.3 below regarding possible utilization of fiber rope solutions for future commerical park mooring system configurations).

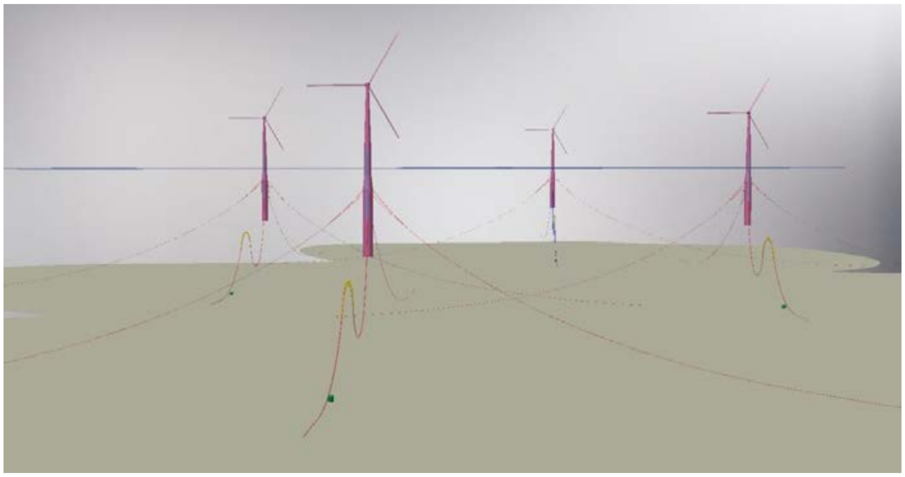

Figure 3: Illustration of mooring configuration

2.1.9 Inter-array cable solution

A preliminary layout of the inter-array cables was considered, however no specific inter-array design workings were undertaken during BP1.

2.1.10 Offshore export cable (static) solution including route to landfall

Based on data from the offshore surveys, a preliminary offshore cable route was identified, as shown in . The total length of the offshore export cable route from under the footbridge in Boothbay Harbor to the edge of lease area is approximately 42km. Based on the geophysical studies conducted, the initial analysis of the 42km route indicates that there is approximately 2km where it will not be possible to bury the export cable. For those areas where burying the export cable is not possible, artificial cable coverage will be required.

2.1.11 Onshore export cable solution (including landfall & route)

Landfall of the export cable will be in Boothbay Harbor. Different onshore cable routes have been evaluated and the resulting options are identified. Selection of the final onshore route would have occurred in later phase and would be conditional upon landowner negotiations and the results of further engineering and environmental analyses. The onshore cable route is estimated to be approximately 2km in total length.

2.1.12 Supply chain and market assessments

The Project has completed an initial screening of potential suppliers to identify those with the technical delivery capacity for the Project. A Market Assessment Questionnaire (MAQ) was sent out to about 40 potential Maine suppliers. Statoil received responses from 13 suppliers. Additional supply chain activities were Initially scheduled for BP1, but was suspended when the Maine specific project activities were put on hold in July.

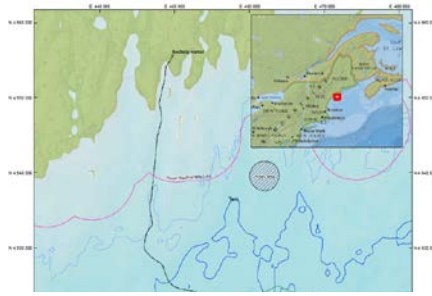

Figure 4 Preliminary offshore export cable route

2.2 NREL Collaboration

To strengthen the project team and ensure that Project lessons learned are captured by U.S. research institutions, Statoil entered into a technology collaboration agreement with the National Renewable Energy Laboratory (NREL) NREL has undertaken central elements within technology development for floating offshore wind and performance monitoring of the Hywind Maine units.

2.2.1 NREL Work Packages (WP)

2.2.1.1 WP1 Design and Analysis (A) and Wake Modelling (B)

WP1 (A) Design and Analysis

For this WP, NREL analyzed the Hywind-II design for structural loads and motions.

NREL's FAST (Fatigue, Aerodynamics, Structures, and Turbulence) modeling tool has been used to simulate a range of load cases to evaluate the proposed Hywind II-design concept. The FAST Code is a comprehensive aeroelastic simulator capable of predicting both the extreme and fatigue loads of two- and three-bladed horizontal-axis wind turbines.

NREL built a 3MW reference FAST7 model based on the Siemen's SWT-3-0-101 to work with Statoil's control algorithm. The model was verified based on the 3MW work done for the Maine site by Statoil. The model has also been used for wake modelling.

Based on the International Electrotechnical Commission's (IEC) 61400-3 ed1.0 on design requirements for offshore wind turbines; and on the American Bureau of Shipping's (ABS) Guide for Building and Classing Floating Offshore Wind Turbine, four suites of strength design load cases (DLCs) have been chosen for analysis , for a total of eleven unique DLCs. The analyses of these DLCs have been limited to structural loads and platform motions. The analysis has considered anchor tension, platform motion, blade root bending moments and tower loads. Based on the analysis four DLCs have been identified as limiting load cases.

In addition, Statoil and NREL have agreed to an extended scope of work to include the following: (1) building a 6MW reference FAST8 model similar to the Siemen's SWT-6-0-154; (2) verification of the model; and (3) assessment of the integrity of the structural design under environmental conditions of a proposed US deployment site. This will be used to assist with the optimization of the substructure, and to assess its expected extreme strength and fatigue. NREL will make a report summarizing a design assessment of the 6MW design addressing strength and fatigue.

The work will be important input to the further optimization of the Hywind design.

WP 1 (B) Report Wake Modelling

The interaction between atmospheric boundary layer (ABL) and wind turbines and their wake influence on the downwind turbines is difficult to model using analytical means. Accurate predictive methods are crucial for turbine siting, optimizing the power output, and reducing fatigue loads.

NREL studied the influence of waking effects from an upstream offshore floating wind turbine on a downstream turbine separated by seven rotor diameters for the Hywind Maine Pilot project. The turbines and the platforms were subjected to atmospheric boundary layer flow using large-eddy simulations using the SOWFA high fidelity simulation tool. Various sensitivity studies related lateral offset position on fatigue loads were performed and validated with high-fidelity tools.

The effects of various lateral positions (-1D, -0.5D, 0, 0.5D, 1D, and 1.5D) of the downstream turbine relative to the upstream turbine were considered. The lateral position has an impact on the turbine performance, structural and platform responses. The load response from the rotor, tower, and the floating platform for the downstream turbine is sensitive to the lateral offset positions where partial waking yields a significant increase in the cyclic load range.

For the given set of lateral positions for the downstream turbine, it was found that the largest damaged equivalent load occurs when the turbine is one-rotor diameter to the left, when looking upstream, of the centerline which is the fully waked turbine position. The damaged equivalent load is the equivalent fatigue load under constant amplitude cycle that will produce the same amount of fatigue damage from the actual load spectrum.

The position associated with the largest damage equivalent loads has been further investigated in a SOWFA simulation, modeling both the upstream and downstream turbines. The increase of the damage equivalent load for the flapwise blade root moment is 45% compared to the upstream turbine which can potentially reduce the turbine service life time. On the other hand, the fatigue load on the downstream turbine placed on the right side of the fully-waked position yields lower stress due to the non-symmetric wake shape.

2.2.1.2 WP2 – Turbine Size Up-scaling

In order to improve the understanding of the system cost of floating offshore wind projects in the US, NREL has conducted a study of the cost drivers for the substructure. The study addresses the use of a Hywind-II 6-MW spar design for a site in the Gulf of Maine at a depth of 220 meters using NREL's Floater Sizing Tool (FST). The FST has been used to estimate the first-order cost of floating platforms based on turbine capacity and met-ocean conditions. The sizing tool was used to calculate weights and dimensions for each of the major platform components based on oil and gas experience.

A Scotland 6-MW Hywind-II design was chosen for mass calibration work due to a lack of a 6-MW Hywind-II design for the Gulf of Maine, even though it is based on a more severe environmental condition than the Gulf of Maine requiring more steel and a heavier platform.

In addition to the chain mooring with longer line lengths in catenary configuration, two types of fiber rope (polyester and aramid) in a semi-taut configuration were examined to potentially lower the mooring cost and seafloor footprint.

Preliminary results indicate that it may be feasible to use fiber rope, but it is not recommended until further detailed strength and fatigue investigations are performed, and it has been successfully qualified for use in an offshore floating wind system by a certification body. If further study proves fiber rope to be economical and technically feasible, the use of the fiber rope may reduce the anchor radius footprint. The most cost-effective fiber rope is polyester, which is not creep resistant, anchored to a pile in a semi-taut configuration.

Most of the platform cost is driven by the size and wind turbine power capacity. A parametric study to investigate the relationship between the Hywind-II spar mass and turbine power for the Gulf of Maine site was conducted using the rotor diameter, tower mass and length and turbine mass. The study shows that there is a linear relationship between these parameters.

2.2.1.3 WP3 – Mooring System

Synthetic fiber ropes are common in offshore oil and gas structures for catenary and taut mooring systems. Deepwater installations benefit from fiber ropes because of their near-neutral buoyant properties, which facilitate handling, installation, and design.

In this WP, the use of fiber rope moorings for the Hywind Maine project in 140 meter water depth was evaluated. The scope of this WP was limited to collecting information for various fiber rope families, investigating their fitness for use in a particular mooring design, and forming recommendations based on the studies performed.

Initially, all fiber rope families were considered (high-modulus polyethylene, polyester, liquid crystal polymer, aramid, and nylon). Based on communications with fiber rope manufactures, the most promising rope technologies suitable for permanent mooring installations consist of polyester and aramid families. The assessment made under this WP was based on static analysis of several synthetic mooring systems.

The results of this WP suggest that 140 meters is too shallow for canted (non-vertical) taut mooring strategies to work. However, it can still be advantageous to use synthetic fiber ropes for future parks at deeper waters. The analysis was performed using OrcaFlex for time domain simulations and NREL’s Mooring Analysis Program (MAP) for all static analysis.

2.2.1.4 WP4 – Instrumentation and Data Acquisition

For the Hywind Maine Pilot project testing and data collection, focus was on two important issues expected to expand on the knowledge gained through the Hywind Demo project: (1) interaction effects between floating turbines in an array and (2) the impact of an optimized foundation with a larger turbine.

For this WP, relevant tests that meet the project objection for at-sea testing of the Hywind Maine Project were identified and outlined. Three testing areas were outlined for at-sea testing of an array of four 3-MW floating turbines: (1) array dynamics; (2) performance of optimized foundation; and (3) long-term monitoring. Each testing area included a subset of tests for which the test purpose, considerations and requirements, and post processing results were detailed out. A comprehensive measurement list was presented for each turbine with each measurement mapped to the relevant test(s). Test matrices were also given. These matrices, which define the desired data sets to be collected, act as pseudo checklists to monitor testing progress.

A methodology was developed for selecting the upstream and downstream turbines. This methodology considers all combinations of upstream and downstream turbines and uses local wind and wave field data to select the combination that maximizes the probability of wake interaction and filling testing matrices. At the Maine test site, the southern turbine is considered the best choice for an upstream turbine and the northern turbine is the best choice for the downstream turbine.

An overview of the current state of the art in lidar technologies has also been provided along with three suggestions for potential lidar configurations.

2.2.1.5 WP5 Economic Analysis

NREL performed an economic analysis of Statoil's floating technology innovations in relation to conventional fixed-bottom offshore wind technology in terms of levelized cost of energy (LCOE). In the report, cost estimates were developed for two Hywind project scenarios in the United States; a 12 MW pilot scale project and a 600 MW commercial scale project. These two scenarios were compared to a baseline scenario defined by DOE that represents the current state of offshore wind technology in the United States.

2.2.1.6 Extended Scope of Work

The extended scope of work includes additional work related to Design and Analysis (expansion of WP1), Wake Modelling (expansion of WP1), a Concept Resource Assessment (new WP) and an Array Cable Study (new WP).

2.3 Construction and Installation Activities

A summary of activities with reference to studies and external work related to the fabrication, construction and installation of the Hywind Maine WTG units is described below.

2.3.1 Fabrication, transport, storage and staging site of the WTG and tower

The base case for the project is to use a Siemens 3 MW direct drive turbine with 101 m, optional 108 m, rotor diameter. Optional wind turbines in the 3MW class were evaluated based on technical maturity, suitability for placement on floating substructure and energy production. The use of larger WTGs was not considered for the Project because the offtake support regime in Maine does not favor an array of 4 - 5 turbines with larger power rating.

WTGs will be manufactured and stored at the WTG vendors manufacturing facilities. Wind turbines will be manufactured at a US or European plant, or a combination thereof. Individual parts will be shipped to a Maine port by sea. After delivery, they will be stored at the staging site or on a barge moored at the floating storage site until assembly of the Hywind WTG Units.

As Statoil already has relevant, satisfactory knowledge regarding WTGs on floaters through its experience with the Hywind Demo installation, no specific WTG fabrication or WTG transport studies for the Hywind Maine project were undertaken during BP1. However experience transfer from the Hywind Demo workings was undertaken.

2.3.2 Substructure Fabrication, Yard Assembly and transport

In accordance with the terms and conditions of the approved power purchase agreement term sheet, the extent of local content (suppliers based in Maine) must be maximized. The following items are assumed manufactured (in full or partly) in Maine:

- Steel substructures
- Onshore cable and electric infrastructure
- O&M base facilities
- Mooring systems (or parts thereof)
- Communication system (or parts thereof)

The steel substructures will require specific yard construction facilities which a limited number of suppliers will be able to perform. Fabrication studies were carried out with two potential fabrication yards in Maine.

The load-out from the fabrication yard will be by either multi-wheel trailers onto a floating barge (as proposed by Cianbro), or by a floating dock. Transportation of the substructure from the fabrication yard will be by either wet-tow or barge transport.

The mooring system (chains and anchors) could be part of the substructure fabrication contract, but it is likely that all, or parts of this system, will have to be subcontracted to other companies, which may be outside of Maine.

Statoil requested vendor proposals for the construction of the Hywind Maine substructure. Two potential vendors responded with studies that provided preliminary pricing estimates and established the capability of the Maine suppliers. Both suppliers were considered capable of delivering to the Project.

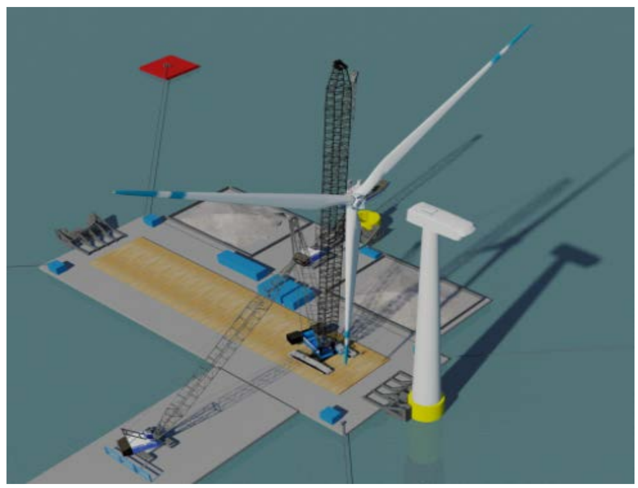

Figure 5: Illustration of inshore assembly

2.3.3 Assembly

The assembly work will be performed at two different locations: (1) an onshore area with a port facility that will be used for storage of WTG components and assembly of the rotor ("onshore assembly site"); and (2) an inshore area that will be used for the upending, ballasting, WTG erection and completion work ("inshore assembly site"). In addition, two storage areas will be required to store components before assembly and assembled units prior to tow to site.

The base case onshore assembly site is the Sprague Terminal at Mack Point. The base case inshore assembly site, chosen to accommodate the substructure during upending, ballasting and WTG erection, is located in Penobscot Bay east of Islesboro Island. (See illustration in Figure 5). However, the ultimate suitability of this site location is uncertain based upon the findings from the bathymetry surveys undertaken in 2013. An alternative assembly site, along the original tow route was being assessed at the time the Project was terminated.

To allow for storage of the fabricated, but not upended substructures and other project equipment, two designated areas were identified as storage areas. These areas are located north of Isleboro with a water depth of 10 - 40 meters. The areas are planned to be used for storage of the substructures before upending and for temporary mooring of vessels/barges involved in the marine operations, etc. In the event the assembly area is relocated, it may be necessary to reassess the suitability of the proposed storage area, as well.

Prior to towing the assembled units to the offshore site, the assembled units may be moored. The temporary inshore mooring location initially selected (but under re-evaluation after tow-route bathymetric survey) is south of the inshore assembly site. At these temporary moorings, commissioning work could also be executed so that the assembly barge could be used as efficiently as possible.

Analysis of the findings of several studies resulted in an updated base case method for the assembly of the Hywind units, pre installation of anchors and installation of the Hywind units. The studies were performed to develop methods applicable to the local conditions in Maine and the US East Coast.

2.3.3.1 Upending and ballasting of the substructure

After fabrication, but prior to assembly, the WTG Unit substructures will be upended and ballasted at the WTG Unit assembly site.

2.3.3.2 Assembly of Hywind WTG Units

After the upending and ballasting of the WTG Unit substructure, the tower and Rotor-Nacelle Assembly (RNA) will be mounted onto the substructure. The RNA may be mounted individually or as a single piece using a floating crane or specialist vessel. This assembly process will be performed at the WTG Unit assembly site. After the assembly process, the WTG Units will be commissioned to the extent possible/practical and temporarily stored at the assembly site awaiting tow to the offshore site

A Hazard Identification Study HAZID covering the assembly operations (including upending and ballasting operations) has been undertaken.

2.3.3.3 Pre-installation of offshore cables and mooring systems

The mooring system will be pre-installed prior to inter-array cable installation and towing to the site of the preassembled WTG Units. (See section below on 'power cables' for information regarding pre-installation of the offshore cables). Tow to offshore site, hook-up and commissioning of the assembled Hywind Units
After assembly at the deep water inshore assembly site, the WTG Units will be towed to the lease area for deployment (including hook-up) and final commissioning. The WTG Units will be towed at a draft of between 60 and 80 m. As a base case, the towing operation will be performed with two vessels. (For the Hywind Demo Project, three vessels were used with one main tug and two assisting tugs). After arrival at the lease area, each WTG Unit will be connected to the mooring systems.

Bathymetry surveys of the towing route and planned assembly sites were performed in the Summer 2013.

2.3.3.4 Fabrication, storage and installation of power cables

Subsea cables will be sourced worldwide and shipped to Maine. Cable installation (as with all other sea activities) will have to consider the Jones Act regulations for the use of transport and installation vessels. From the manufacturing facility (or other temporary storage location) the cable(s) will be loaded onto cable installation vessel(s) and installed. If the cable is to be stored after manufacturing it is anticipated that this will be done onshore at either the manufacturer's facility, or on a barge at a floating storage site.

It is anticipated that the export cable will be installed before the WTG Units are moored offshore. The static parts of the export cable will be buried to approx. 1 m depth using a vessel with specialist cable burial equipment such as trenchers, ploughs or jetting. The final method of cable installation will depend on seabed conditions along the export cable route.

The infield cables may be installed before or after the WTG Units are moored offshore. The infield cables will be installed from an installation vessel. To stabilize the cables at their touchdown points, anchors (e.g. weighted), sand-bags or rock dumping may be used. It is not anticipated that the infield cables will be buried, although depending on additional analysis of the cable dynamics and layout considerations, certain parts of the cable may be buried.

When the infield cables (and export cable) have been installed they will be pulled-in, hooked-up and commissioned along with the rest of the offshore installation prior to first electrical export.

2.3.3.5 Onshore construction activities including export cable and substation modification workings

The installation of the landfall portion of the export cable is planned to be performed from a moored barge with a reel. The barge would be positioned in Boothbay Harbor basin approximately 600 – 800 meters from the landfall point. The landfall end will be floated out using buoyancy elements and pulled in to landfall using an onshore winch, while guided by work boats. The rest of the landfall portion of the export cable will be laid from the barge. The entire route of the landfall cable is shallower than 15 meters at Lowest Astronomical Tide (LAT).

The export cable will be connected to the Boothbay substation just outside Boothbay Harbor.
CMP and ISO-NE conducted a System Impact study during BP1 which documents the necessary modifications to be undertaken, based on the use of the Base Case WTG..

2.4 Operation and Maintenance

A Hywind Maine Operation and Maintenance Philosophy was prepared, which documents the base case and alternative operating strategies for the Project. There are two main objectives for the set-up of operation and maintenance:

1) Ensure safe and reliable operations of the wind turbines throughout the lifetime of the wind farm; and
2) Ensure that all project objectives and goals that require operational data are followed up to the extent necessary.

Safe and reliable operation and maintenance: With only four turbines, it is anticipated that the workload in the operational phase will be relatively low and will, therefore, not require a dedicated operational center with back-office functions. With the time difference between Norway and Maine, it may be a challenge to follow up and plan maintenance activities in a proper way without affecting turbine availability and increasing cost. The base case for operation and maintenance is therefore to enter into an all-inclusive operation and maintenance agreement either with the turbine supplier or a third party O&M provider. This agreement would also include marine operations, necessary control room functions and, if needed, daily communication with grid owners, etc.

Meeting project objectives and goals: To ensure that the project objectives can be met, it is important that quality data and information is secured and made available for the parent organization (Statoil) in Norway. To ensure this, a proper infrastructure is essential. A proper evaluation must be performed to establish which measurements, data quality/resolution, IT-systems, etc. are needed. Detailed evaluations related to this topic take place in later project development phases.

2.5 Environmental and Permitting Process

2.5.1 Project site planning and studies

A Site Characterization Report ("SCR") was completed and submitted to BOEM for review in June 2013. The report contains the impact assessment screening process (e.g. constraint mapping, initial stakeholder consultation) conducted by Statoil prior to site selection to identify the key issues to be further addressed in the Impact Assessment process. The report also includes an overview of the regulatory framework, a description of the baseline conditions in the Project area, the proposed alternatives and the proposed studies that were to be conducted to ensure a good basis for the environmental impact assessment process. The SCR was created to provide a detailed level of information for BOEM's review, which would enable the initiation of the scoping process, although it does not include all of the technical details and information required to be in a COP.

Field survey status and results

Tetra Tech, Inc. (TT) was contracted as Statoil's local Environmental Impact Assessment coordinator. During BP1, TT completed the first year of avian and bat studies and moved into the second year of data gathering. A report summarizing the first year of data was prepared. A brief summary of the first half of the second annual cycle of avian surveys (June 2013 – October 2013), and a cursory assessment of the survey results and efficacy of the surveys is also provided in the report. The avian and bat surveys were conducted according to plan and provided important data in a region where data on abundance and distribution of avian and bat species offshore generally is limited. Important lessons on appropriate methodologies for these type of surveys were also a valuable output of the studies. Statoil also shared the results of the avian and bat surveys with BOEM. The data collected will be included in the 2014 baseline maps for the Atlantic, prepared by BOEM, USGS and NOAA.

In addition to the avian and bat surveys, initial wetland delineation and vernal pool surveys were conducted along identified potential onshore cable routes. The terrestrial archeological surveys were initiated, but were not completed before the project was put on hold. The survey protocols for all marine surveys (e.g. geophysical, marine archeological and benthic marine) were developed and issued, with agency review and approval. The marine surveys were also initiated and are further described in chapter 2.5.2.

2.5.2 Environmental and design parameter studies

2.5.2.1 Geophysical study

Alpine Ocean Seismic Survey was contracted to perform the geophysical surveys for the lease site and offshore cable route during 2Q 2013. The geophysical survey consisted of an integrated suite of sensors using Differential Global Positioning System (DGPS), multibeam echosounder, sidescan sonar, sub bottom profiling, magnetometer and Ultra Short Baseline acoustic positioning system. In addition to the lease area and cable route, a bathymetry survey was performed for the tow route to determine minimal water depths. It was confirmed there are several areas along the proposed tow route that are not sufficient for the designed tow depth. Due to postponement of the Maine-specific activities in July 2013, the scope was reduced for the latter parts of the survey, and a benthic and video survey was not performed. However, even with a reduced scope, the results provide important data that can be used to select the turbine locations, cable route, assembly site and tow route. Marine Mammal observers (MMOs) were onboard the vessel and on watch during all survey activities.

Significant areas of bedrock were identified during the surveys, which will have an impact on the route selected for the offshore cable, as well as on the anchoring solution for the wind turbines. A full geophysical report including charts and data was generated on completion of the project. These data were used to assist with the design basis work and scoping activities for the selection of the assembly site, tow route, and offshore cable route. Despite the reduced scope of study, Statoil received confirmation from BOEM that, subject to a few additional line fills being completed, the geophysical study results meet BOEM's requirements for the COP.

A complete Submerged Cultural Resources Investigation (Marine Archaeology) report was produced by Panamerican Consultants based on data gathered during the geophysical survey and from a maritime history desktop study. This report concludes that some areas containing unknown targets (eg debris, rocks, trash, chain, UXO's or old fishing gear) should be avoided or reviewed with video prior to installation activities.

2.5.3 Agency engagement and stakeholder management

Statoil believes that early and open agency, and public outreach leads to a more streamlined and effective permitting process for any proposed Project. It also gives the potentially affected stakeholders the opportunity to express their views at an early stage and allows Statoil to address issues early enough to avoid, minimize, mitigate or offset potential adverse effects (in that order) and emphasize potential beneficial impacts of the development. Accordingly, since the earliest stages of project development back in 2009 through the termination of the Project in October 2013, Statoil conducted multiple meetings with regulators at both the Federal and State level to discuss the Project, the permitting schedule, survey protocols and other relevant issues.

Statoil submitted an Unsolicited OCS Lease request to BOEM in October 2011 and thereafter began preparing a COP. During the first half of 2013, Statoil and BOEM were in discussions regarding a Collaboration Agreement outlining the procedure for selecting a third party environmental coordinator for the review of the COP submission, expected to be filed with the regulator in Q4 2013. At the time the project was put on hold (Summer, 2013), discussions regarding the contents of this agreement and the timing of the review were ongoing.

In addition to maintaining regular contact with staff members at the relevant regulatory agencies,, Statoil has also established and maintained a good dialogue with local stakeholders who could potentially be affected by the Project, eg. fishermen, the environmental community, and potential suppliers. In 2011 Statoil entered into a collaboration with the Island Institute in Maine to assist with initial outreach efforts to local fishermen and lobstermen. Building on that foundation, Statoil hired Power Engineering, Inc. to assist the Project team with local Maine stakeholder outreach. Statoil also hired a Maine Fishermen Liaison Officer ("FLO") to engage the local fishermen and lobstermen in a constructive dialogue regarding the Project's impacts, and a Fishermen Research Officer ("FRO") to support the mapping of fishing activities.

In March 2013, Statoil presented the Project at the Fisherman's Forum in Rockland, Maine. In addition and in collaboration with the FLO and FRO, Statoil held a series of meetings in May, where key local fishermen were invited to learn about the Project and engage in a discussion with Statoil representatives. The reaction of the fishermen who attended these meetings was largely positive, with many of the comments and questions related to better understanding the nature of the project, rather than being opposed to the project in general. Most of the questions stemmed from concerns related to siting, whether the entire site proposed for lease would be cordoned off from use and the general footprint of the installations.

Statoil developed a Hywind Maine Stakeholder Management Plan and an Authority Communication Plan, which describe how the company would engage both the general public, as well as interested stakeholders in the community and at the agency level.

2.6 Grid Interconnection

2.6.1 Status grid Interconnection

Grid Interconnection

Statoil filed an interconnection request with the ISO-NE in November 2011. As part of the grid interconnection process, a System Impact Study ("SIS") was completed during BP1 in order to determine if the Project will create any significant adverse impacts to the reliability and/or operating characteristics of the Central Maine Power transmission system. The results of the SIS showed that the Project will not produce any such significant adverse impacts. Furthermore, the SIS concluded that the proposed substation for interconnection in Boothbay Harbor will be suitable with minor upgrades.

In May 2013, Statoil had the option to request a Facilities Study to be conducted by ISO-NE or to move directly to an expedited negotiation of the Small Generator Interconnection Agreement ("SGIA"). The purpose of the Facilities Study is to have the utility examine and provide an initial cost estimate of the equipment, engineering, procurement and construction work needed to implement the conclusions of the SIS. Statoil elected to waive the Facilities Study and SGIA negotiations began in July 2013. The negotiation of the agreement was completed and the parties had a few remaining dates on the milestone schedule to agree to, when the discussions were stopped due to the termination of the Project. Subsequently, Statoil withdrew its Interconnection Request.

Forward Capacity Market

Pursuant to the approved power purchase agreement term sheet Statoil negotiated with the Maine Public Utilities Commission (the "Commission" or "MPUC"), Statoil was required to qualify for the ISO-NE Forward Capacity Market ("FCM"). In June 2013, Statoil submitted a qualification package in order to commence the qualification process for FCM 8. In October 2013, Statoil withdrew from the qualification process as a result of the termination of the Project.

2.6.2 Power Offtake agreement

Under the Ocean Energy Act passed by the Maine legislature in 2010, a Request for Proposals ("RFP") 0 was issued in order to help support demonstration wind and tidal parks with an above market power purchase agreement. Statoil was selected to pursue contract negotiations with the MPUC. Statoil worked with the Commission Staff for over a year to develop a Term Sheet outlining in detail the major commercial provisions of the proposed contract. Among other provisions, the term sheet provided that the relevant utility (determined to be Central Maine Power) would purchase 100% of the power generated from the Project for a term of 20 years at a rate determined by a pricing formula in the agreement. In addition, the term sheet also contained several local content requirements that Statoil was obligated to comply with or face either a penalty fee or the possible termination of the agreement. On January 24, 2013 the Commission approved the Project term sheet and directed the Central Maine Power Company to enter into a power purchase agreement consistent with the provisions of the term sheet.

Shortly after the approval of the term sheet, Statoil started to draft the power purchase agreement. In May 2013, negotiations with the MPUC Staff and CMP began. Over the course of the summer, there were several exchanges of the drafts and multiple negotiation sessions held. The bulk of the negotiations revolved around a handful issues: termination rights, credit support, local content requirements and a tracker mechanism for ensuring compliance with the rate cap mandated by the Ocean Energy Act. These issues were primarily ones of drafting and not conceptual issues, and were expected to be resolved successfully.

In light of the amendment to the Ocean Energy Act passed by the Maine legislature in June 2013, Statoil notified the MPUC in July that it would place the Project activities on hold until the full impact of the amendment to the Project could be determined and a new risk profile for the Project could be developed and approved. On October 28, 2013, Statoil formally withdrew its application from the MPUC RFP process.

3 Progress regarding innovations leading to potential reductions in LCOE

As stated in Statoil's application to the DOE, the project's contributions to cost reduction follow two paths:

- Path 1: Optimize the Hywind concept and develop the supply chain to reduce costs as much as possible for the Hywind Maine Project, while carefully controlling the technical risk of the project;

- Path 2: Up-scale the Hywind design with regard to turbine and substructure size as well as quantity for development of large commercial parks, and introduce new technical innovations to achieve further cost reductions

For the Hywind Maine Project, Statoil planned to demonstrate cost reductions through optimization and up-scaling of the spar foundation design and the pitch controller, better utilization of infrastructure and vessels during installation, development of the local supply chain, streamlining of fabrication, more efficient project execution, more efficient operations, and other measures to be identified as the Project matured.

3.1 Innovations related to the Hywind concept

The Hywind concept presents several advanced technology innovations that can lower the LCOE for offshore wind in the US by increasing production of the wind farm, decreasing floating turbine capital costs, balance of system capital costs, and, operations and maintenance (O&M) costs. Deploying a multi-turbine wind park with floating substructures is technology advancement in itself. As of February 2014, 4 full-scale wind turbines are in operation on floating platforms, one in Norway (Hywind), one in Portugal (Windfloat) and two in Japan, but none of them in multi-turbine arrays. Floating platforms introduce opportunities to access better wind resources in deep waters that would be cost prohibitive for bottom-fixed substructures. With limited water depth restrictions, floating platforms can also support wind farms at distances sufficiently far from shore to avoid near-shore siting restrictions, such as visual or environmental impacts.

The Hywind concept includes several technical advancements that are expected to lower the cost of offshore wind energy. The relatively simple hull design of the Hywind concept is well suited for automated mass production and should not require fabrication yards to add sophisticated specialized equipment. The low waterplane area of the Hywind design reduces the sensitivity to the wave environment, which leads to an efficient substructure with a low steel weight and moderate mooring loads. Thus, the Hywind concept can employ a simple, relatively low cost mooring system. The Hywind design is turbine independent. Any qualified offshore wind turbine can be used, so the Hywind concept can continually benefit from technical advancements made by turbine manufacturers that increase reliability, increase energy capture and/or lower costs.

The ballast-stabilized Hywind WTG unit can be towed to and from the project site in its vertical, upright position using standard tugs. This enables Statoil to employ innovative assembly and installation procedures that avoid the use of expensive specialized vessels and equipment and limit the amount of weather-sensitive work conducted at the project site, reducing costly wait times. These benefits can also be extended to the O&M strategies implemented throughout the life of the project.

3.2 Design optimization and up-scaling

Based on the experience from Hywind Demo, the Hywind pilot park design has been optimized, and design margins have been reduced (see section 2.1). An important part of a pilot project will be to demonstrate that the performance of the turbine is within the requirements when mounted on the optimized substructure. Statoil is developing a broad variety of designs, for both benign and harsher conditions, and has developed an up-scaled design of Hywind both for a 3 MW turbine, intended to be used for the Hywind Maine project, but also for a 6 MW design, intended to be used for a pilot park in Scotland, the purpose being to demonstrate the feasibility of up-scaled Hywind conceptual designs. Both designs are considered to be technically feasible solutions when it comes to design, fabrication, installation and operation. However, there is further technical development work do be undertaken related to floater motion control and the mooring system. A number of studies have been carried out to determine whether the pilot project can be developed with larger WTG/rotors, including advanced fully-coupled dynamic analyses to assess the effect of un-symmetric load effects on floating WTGs with large rotors, assessment of un-symmetric wake loading on floating units in a park configuration, further development and optimization of the floater motion control system, and more advanced mooring system analysis. The NREL work is assisting with securing the feasibility of these conceptual goals (see 2.2.1).

One particular area of investigation, when it comes to turbines with larger rotor diameters, is the effect of the increased wind loads on the yaw and roll motion on the floater, and the design of the mooring system to obtain correct stiffness. Detailed numerical simulations will be carried out to study these effects in more detail for future projects, but in the end it is critical to demonstrate the performance concept in full scale. It is a continuous on-going effort to improve and optimize the floater motion controller for Hywind. Work is still ongoing on the Hywind Demo to test out the controller in different sea states to cover as many conditions as possible, and analyses are on-going to improve the controller to be able to control the motions also in yaw and roll, in addition to the pitch motion.

Several of the NREL work packages as described in 2.2 are relevant for design optimization and up-scaling (WP1 Design and analysis, WP1 (B) Wake Modelling, WP2 Turbine Up-Scaling, and WP3 Mooring System).

3.3 Wake effects for floating WTG

Motion response of a floating wind turbine in a park configuration with multiple units needs further investigation, both through simulations and full-scale demonstration. Wake effects on bottom-fixed structures have been studied extensively previously, but the focus has so far been on the wake loss when it comes to production. For floating WTG units, the critical aspect is rather the effect of the wake on the wind loads acting on the floating turbines in the wake, and how the non-uniform wind loads in the wake affect the floater motions.

Wake interaction effects between floating wind turbines were analyzed in numerical simulations by NREL (ref Section 2.2.1.1). Nevertheless, since this is a new research topic, it will be essential to carry out full-scale measurements in the pilot park to verify the findings. For this reason, the park layout and turbine spacing for a pilot park will be chosen so that it is representative of the wake effects that will be present in a large park, and not so that wake effects are completely eliminated, even if that could have been achieved in a small park, eg. one with only four units.

3.4 Substructure Innovations

The conceptual design work that has been carried out after Hywind Demo has focused on achieving a fabrication-friendly design, which is suitable for efficient serial fabrication. Fabrication studies have been carried out with yards in Maine to ensure feasibility and evaluate potential fabrication methodology.

Significant scale effects have been identified when going from one unit to several units. During a pilot project it will be important to monitor the fabrication processes closely, to evaluate the efficiency gains from the first to the last unit, and also to identify areas where improvements can be made to obtain additional scale efficiencies for future large park fabrication.

3.5 Assembly and installation innovation

The assembly and installation operations are considered as one of the main benefits of floating WTG units, since most of the operations can be carried out in-shore in sheltered waters, and the amount of offshore operations are minimized. Still, there is a significant potential in optimizing the assembly and installation operations when it comes to selection of vessels and equipment, ports, logistics, etc.

The base case for the pilot park is to carry out the assembly and installation using method similar in principal to that which was used for Hywind Demo, which is considered to be efficient for relatively few units, such as for the Hywind Maine project. The pilot project was intended to be used to demonstrate that by using the proven Hywind Demo method, but optimizing the logistics and vessel utilization, the unit cost of installation would be reduced. Similar effects will be studied for the Hywind Scotland project.

At the same time, there is also work ongoing in Statoil to evaluate more innovative and possibly more efficient installation methods, such as onshore turbine assembly. Such methods require specialized equipment with an associated capital expenditure, and it is therefore assumed not to be commercially feasible to be applied in a pilot project with a limited scale. However, it will be considered whether such solutions may contribute to reducing the cost for larger projects, and whether it could be possible to test out parts of the solutions in the pilot project in Scotland.

3.6 Demonstration of new technology

To the extent possible/practical, the Hywind Maine pilot park was intended to be used to test out and demonstrate new technology which has the potential to reduce the LCOE for future large Hywind parks.

One example of alternative solutions that Statoil considered for application in the Hywind Maine pilot park is the use of torpedo or self installing anchors. These anchors are driven into the soil by gravity force. The benefits compared to traditional anchor types are that the anchors can be installed in a very expedient way, since no pulling force has to be provided by the anchor vessel. However, given the results of the survey work done in BP1, it was determined that torpedo anchors are not optimal for the Maine site due to soil conditions.

Another anchor solution under investigation was to use common/shared anchors that could support mooring lines from several turbines. Since the total number of anchors required would be reduced, both anchor costs and installation costs would be reduced.

Suction Embedded Plate Anchors (SEPLA) were also under investigation as a possible alternative. This solution combines features from both suction piles and plate anchors. The intention with this anchor type is to increase the anchor holding efficiency and thereby reduce the anchor cost.

The NREL work package investigated whether fiber-ropes for the mooring lines would be preferable to chain (ref Section 2.2.1.3). Fiber ropes have the potential to reduce the mooring line footprint, weight, and cost, as well as to simplify installation. This solution may have a significant potential for future large parks in deeper waters.

Alternative solutions for cable connection would also have been considered. For the Hywind Scotland project, a study will be undertaken to evaluate whether the cable can be free-hanging and connected directly to the access platform, instead of going through a J-tube connected to the substructure. This could potentially reduce the steel weight of the substructure, as well as simplifying the cable connection operation.

Safe and efficient personnel transfer and access to offshore wind turbines is essential to the technical availability and production regularity of the installations, and has a potentially significant effect on the Cost of Energy. As for Hywind Demo, a pilot park project can successfully be used to develop and test alternative access systems and personnel service vessels.