# Effective Project Planning, Budgeting, and Risk Assessment for Offshore Wind Farm Installation and Marine Operations

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**Abstract:** Effective planning and budgeting is critical to the economic viability of an offshore wind project. With ship and fuel costs at all time highs, the cost versus reward benefit of effective planning can become very significant, very quickly. Marine assets are demand driven and current demand is very high. This demand is primarily driven by the unprecedented boom in the oil and gas industry and the current high operational tempo in the submarine cable industry. Offshore vessel demand is projected to remain high even with 800+ vessels coming out of the shipyards over the next 24 months. Operational costs, asset availability, and market drivers as well as the trends and market projections for the next 3-5 years, are all factors which must be assessed. Given this demand and high ship day rates effective planning of offshore operations is imperative. Experience has proven that proper planning can significantly reduce the cost of operations and the associated operational risks. Risk based planning – financial, technical, and schedule – is key to the successful execution of offshore/underwater operations. Risk models should also include Life of Field Service (LOFS) impacts. This paper identifies and profiles the current cost and availability of different classes of marine assets needed to support offshore wind development and how these factors should be included in the project development cycle and the budget process. Current day rates of $30K plus for support vessels to $100K plus for cable installation ships demand careful planning and management.

## Introduction

Offshore wind development will be a key part of achieving energy security and independence for the US. The offshore advantages of increased power generation/concentration, power consistency and reliability, and proximity to major concentrations of users and the power grid cannot be ignored. The challenges of working in the harsh offshore/underwater environment and the associated costs are critical factors which must be considered during the project planning and budgeting cycles. The purpose of this paper is to present an approach for planning, budgeting and assessing the risks associated with the marine segments of an offshore wind farm development. This includes a discussion of operational costs, asset availability, and market drivers as well as the trends in the marine market. The impact of associated industries (oil and gas, submarine telecommunications) on the marine asset supply chain will also be examined.

## Project Planning and Development Process

Figure 1 presents a top level overview of the project development process for an offshore wind farm. The description of the development phases and how the Offshore Work Plan factors into the project decision matrix is described.

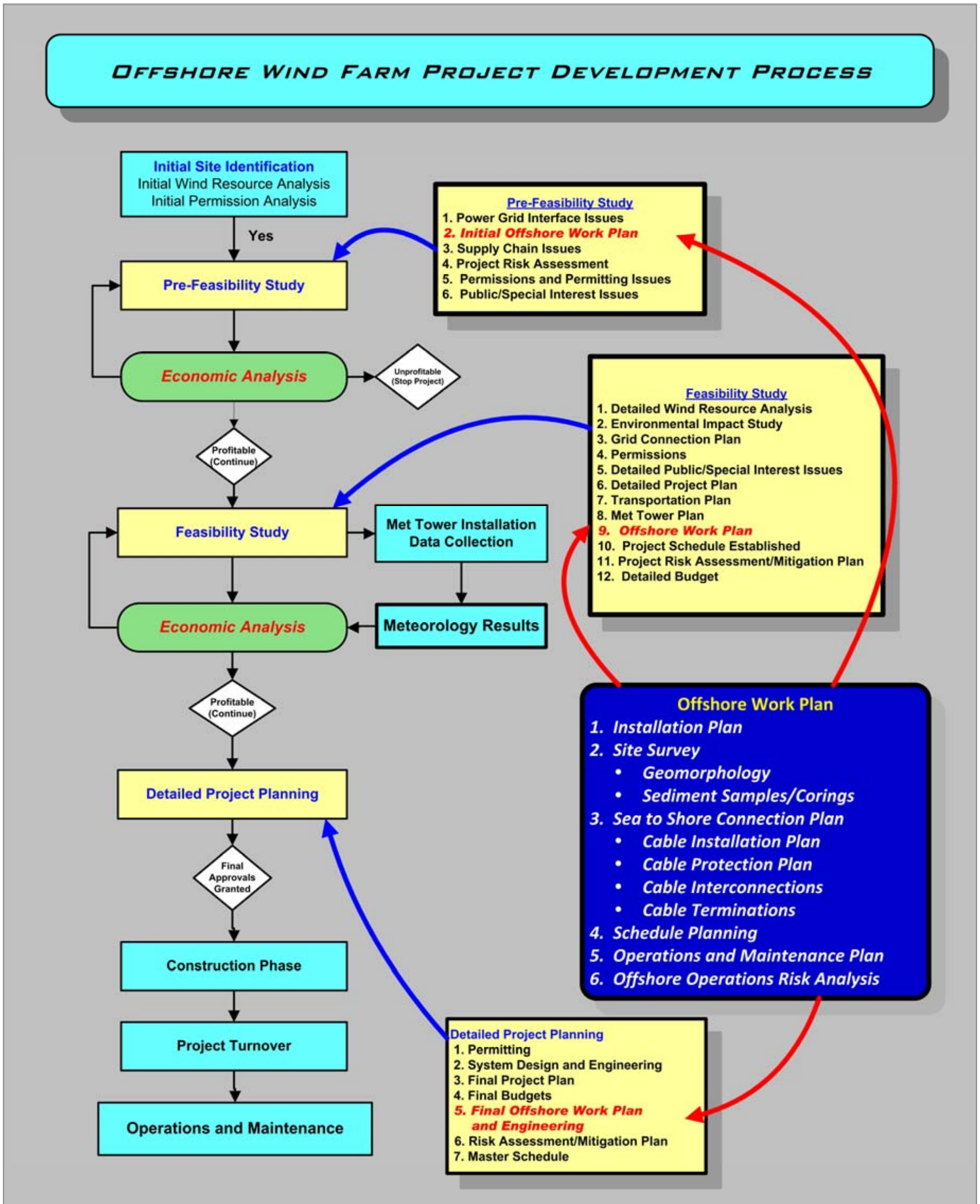


**Figure 1. Offshore Wind Farm Development Process**

## OFFSHORE WORK PLAN

The Offshore Work Plan is a key document that should be started during the Prefeasibility Study and becomes more detailed as the phases of the project progress. It examines the most cost effective and efficient approach to the offshore work. There are a number of different approaches that can be taken and depending on the specific project characteristics significant savings can be realized as the approach is optimized. The main segments of the offshore work plan are:

- **Installation Planning**. This segment of the plan addresses how the turbine systems are to be installed and how the installation marine assets can be leveraged to make the other segments more cost effective. One of the major goals is to maximize the opportunities to perform as many of the offshore operations as possible in parallel.
- **Site Survey**. The site survey plan examines the geomorphology of the potential site(s) and sediment composition. This information is critical to the foundation designs and the sea-to-shore subsea transmission cable plan.
- **Desktop Study**. The Desktop Study (DTS) is the critical part of the installation planning process whereby the marine cable route and subsea sites are technically evaluated based on available public information. Critical criteria such as permitting, environmental conditions, tidal conditions, weather conditions, local government agencies for permitting, fishing activity, etc., are all part of the analysis provided in the DTS. The DTS is integral with the Site Survey but includes a much broader scope.
- **Sea-to-Shore Connection Plan**. This plan addresses the elements required to transmit the generated power to shore. As will be discussed below when the insurance claim history associated with the European offshore wind industry is examined subsea cable issues comprise 80% of the claims paid. Lessons learned strongly indicate that developers should focus more resources on getting the Sea-to-Shore connection right.
- **Schedule Planning**. The offshore work will be a significant factor in the overall schedule of the project. Operational weather windows must be considered within the master schedule. It is critical to optimize the time of the year in which the offshore activities will be performed in order to minimize the weather down time. The biggest costs associated with the offshore operation are the day rates of the marine assets which are payable whether the asset is working or on stand-by waiting for the weather to clear.
- **Operations and Maintenance Planning**. This segment of the plan deals with the Life of Field Service (LOFS) issues associated with a project. The requirements to operate and maintain an offshore wind farm are very different and much more costly than on-shore installations.
- **Offshore Operations Risk Analysis**. It is critical to identify the risks associated with the offshore work and be pro-active in mitigating them. Risks associated with marine asset availability, support infrastructure, weather, subsea sediment conditions, and installation are huge cost drivers. While the risk associated with offshore operations can never be mitigated completely it is paramount that they be mitigated to the extent possible and reasonable.

In summary, the Offshore Work Plan should be a dynamic document that becomes progressively more detailed as the project phases advance. In addition, it is critical that planning for offshore operations be started early and continues throughout the project. This approach allows the developer the opportunity to significantly reduce development costs and maximize Return on Investment (ROI).

## PREFEASIBILITY STUDY

The Prefeasibility Study is the phase where the first, top level decisions concerning the project are made. Once it has been determined that the wind resources and initial permission requirements are acceptable the Prefeasibility Study can proceed. The top level elements of this phase are shown in Figure 1. Other elements are included as required. The Initial Offshore Work Plan should be established in this phase. The key characteristic of this initial plan is to examine the available subsea and environmental data to attain a first look at the offshore work conditions:

- **Installation Planning**. Location of marine assets and transit times can be major cost drivers which must be considered and accounted for in the original budget. In addition, an analysis of the operational weather window that can reasonably be expected versus weather-associated down time is examined.
- **Site Survey**. Existing geophysical and bathymetric data provides details of the bottom morphology, sediment composition, depth of the bedrock layer, ocean current, tidal fluctuations, expected sea states, existing subsea cables and pipelines, shipping transit lanes, fishery patterns and habitats, and other information that can enter into the initial siting decisions. Environmental conditions can vary significantly over a relatively small area and the proper site selection to minimize installation costs is critical.
- **Desktop Study**. It is during the Prefeasibility Study that the DTS takes its initial form. All of the required elements are identified and the risk elements identified. During this phase all of the available information is examined in order to formulate an initial assessment of the offshore requirements of the project. Critical criteria such as permitting, environmental conditions, tidal conditions, weather conditions, local government agencies for permitting, fishing activity, fishermen groups, social conditions, etc., are all part of the analysis provided in the DTS.
- **Subsea and Ocean Engineering**. The engineering required during the Prefeasibility phase focuses mainly on identifying all of the major engineering elements which must be addressed, identifying the associated top level risks, and performing of initial trade-offs to determine the best approach. During this phase the engineers maximize the use of existing information to establish the initial engineering baseline. This includes all elements of the project including offshore power consolidation, subsea engineering of the cable and protection plans, terminations and intra-tower connectivity.
- **Sea-to-Shore Connection Planning**. Available survey data can provide an initial cable routing and protection plan. The cable and its installation are major budget and schedule drivers with long lead-times. Early planning will allow for these high impact components to be minimized and provide the basis for a realistic budget. In addition, it may be more effective to plan for transmitting the power subsea versus over terrestrial routes. There are cross over points where subsea transmission is more cost effective.
- **Schedule Planning**. Schedule planning addresses operational weather windows

and how to plan the offshore work in the most efficient manner. For instance, if the number of towers to be installed at a given location requires installation to occur over two weather seasons this could impact how the field is phased and brought on line. In addition, this might drive certain fields to consider the purchase of a smaller number of larger capacity turbines which could be installed in one season and thus bring the full capacity on line faster. The reduction in installation costs and a shorter schedule may offset the costs associated with procuring and installing larger turbines.

- **Operations and Maintenance (O&M) Plan**. O&M planning in this phase is at a high level and would be evaluated in terms of resident infrastructure requirements to support the field and in the initial evaluation of candidate turbine systems.
- **Risk Analysis**. Risk elements should be consolidated within a risk matrix so trade offs between the risk elements can be assessed. The driver in this assessment is optimizing the Return on Investment (ROI) for the project.

In summary, the main objective in the Offshore Plan during the Prefeasibility Study phase is to leverage the existing data resources to provide a top level assessment of the offshore elements of the project. Under most circumstances analysis of this information provides a basis to assess whether there are any 'abnormal' offshore conditions which should be included in the risk matrix and a determination as to how these risks might be mitigated and the associated costs.

## Feasibility Study

The two main differences between the Prefeasibility and Feasibility Studies are:

- Level of Detail. The level of detailed required during the Feasibility Study phase is much greater than the Prefeasibility phase, and
- Empirical Data Generation. It is during the Feasibility Study that site specific information is generated as it relates to the specific project characteristics and requirements.

The Feasibility Study brings together all the project elements which need to be evaluated and addressed. With regard to the Offshore Work Plan, the details are much further defined for every work segment. The main empirical data that is generated for the Offshore Work Plan is the underwater survey and the sediment sampling. The survey data will allow the engineers to establish the optimum Route Position List (RPL) for the subsea cable and establish where the cable will terminate on shore. Sediment data allows the foundation engineers to design the tower foundations and plan for their installation. In addition, this information is used to establish a cable protection plan which is critical for the life cycle of the cable.

During this phase it is important to generate the Operations and Maintenance Plan and to feed the data into the Life of Field Service budgets. In addition, the risk analysis matrix is much more detailed and the mitigation plans are established for the identified risks.

## Detailed Project Planning

- Subsea and Ocean Engineering. The Detailed Planning phase focuses on final system design and engineering. This includes all elements of the project including offshore power consolidation, subsea engineering of the cable and protection plans, terminations and intra-tower connectivity. It is essential to begin the engineering early in the development process.

- Final Offshore Work Plan. It is during this stage that the final work plan is established. This plan is detailed with actual bids and availability of assets. Definitive schedules are established which are used to determine which marine assets are available in the time frame required to support the offshore work. The plans for tower and subsea cable installation are finalized and the Master Schedule established. In addition, supply chain issues are finalized.

## Risk Assessment

Identifying, evaluating and addressing risk factors throughout the life of an offshore project can significantly impact system cost and reliability over its planned life. Risk analysis should be undertaken during the early phases of feasibility assessment. Risk management considers the possible outcome of future events and actions that can positively influence those uncertain outcomes. Dealing with risk uncertainty requires identification of possible outcomes and analysis of event probabilities versus the consequence of occurrence. The goal is to identify risks that warrant mitigation intervention.

Three basic propositions are presented in this paper:

**Proposition 1:** Effective system level risk management practices focused on stakeholder Return on Investment (ROI) should be the over-arching project decision making tool.

**Proposition 2:** Effective maximization of ROI requires system level risk management to begin in the Prefeasibility Study phase.

**Proposition 3:** System level risk analysis must include all of the phases of the system life up to decommissioning.

### Proposition 1: ROI Should Be the Over-arching Decision Making Tool

The primary tenet of this proposition is that Return on Investment (ROI) is the sole driver for the viability of the project and that the over-arching project risk is that the system 'investors' or 'stakeholders' will not achieve their Return on Investment (ROI) over the life of the project. This tenet dictates a hierarchical structure to risk with ROI risk being at the highest point. All other risk elements are subordinate to the ROI risk. A top level presentation of the risks associated with an offshore wind farm is shown in Figure 2.

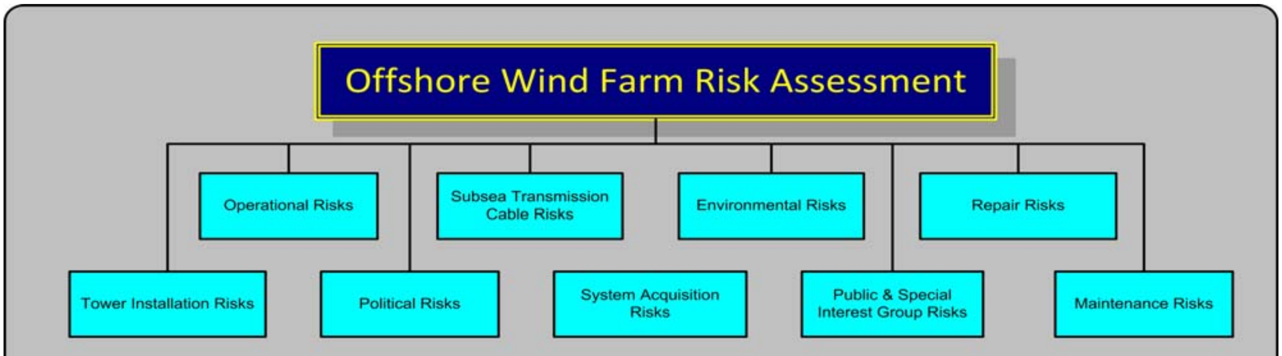


Figure 2. Risk Assessment

**Proposition 2: Effective Risk Management Begins at Prefeasibility Study**

This proposition is centered on the desirability to bring forward an effective risk analysis methodology to support more informed decisions by the stakeholders during the Prefeasibility phase. At a very top level, ROI models are built around the cost of system acquisition and operation, the longevity and volume of the revenue stream (Power Purchase Agreements) and the ability to price services to meet or exceed the expected rate of return. The more accurate and complete these models are at the feasibility phase the more informed the project decisions will be. The modeling system presented in the paper is capable of providing a much broader and more accurate data set on which to base critical Go/NoGo decisions.

**Proposition 3: Risk Analysis Should Include Full System Life Cycle**

ROI analysis is based on the expected return on investment over the entire planned system life. It is absolutely essential that all of the project elements are examined as system level decisions are made. Decisions are made during the Prefeasibility and Feasibility phase which will set the project course and which address major risk considerations associated with the project. It is critical that these decisions are made with the knowledge of how they will impact each phase of the system life. The information exists today to create a whole life system model during the feasibility phase which will allow the decision makers to establish the project strategy based on a much larger and more complete picture of the entire project. In order to do this effectively each element of the project must be modeled and as decisions are made the impact of those decisions are simulated in order the that full impact can be predicted. Very few 'decisions of consequence' are so stove-piped that they do not impact other project functions. It is essential to understand the ripple effect before final implementation.

The specific topics associated with the risk assessment vary with each project and invariably as the elements of the project become more defined new risks surface which must be considered in the decision matrix. Risk assessment is a dynamic project tool that must be updated at every stage of the project. The actions taken to mitigate project risk will affect the overall project capital cost structure and eventually the ROI.

## LESSONS LEARNED

It is important that US developers take full advantage of the lessons learned from the European offshore wind industry. With a number of fielded projects there are numerous lessons learned that can be leveraged into reducing project risk and making future projects successful. One of the methods for quantifying the problems and failures encountered in offshore wind development is to look at the insurance claims which have been filed and paid out. Claim patterns can be a strong indicator of areas where more attention is needed within new projects. Figure 3 below shows the claim history for the European Offshore Wind Farms.

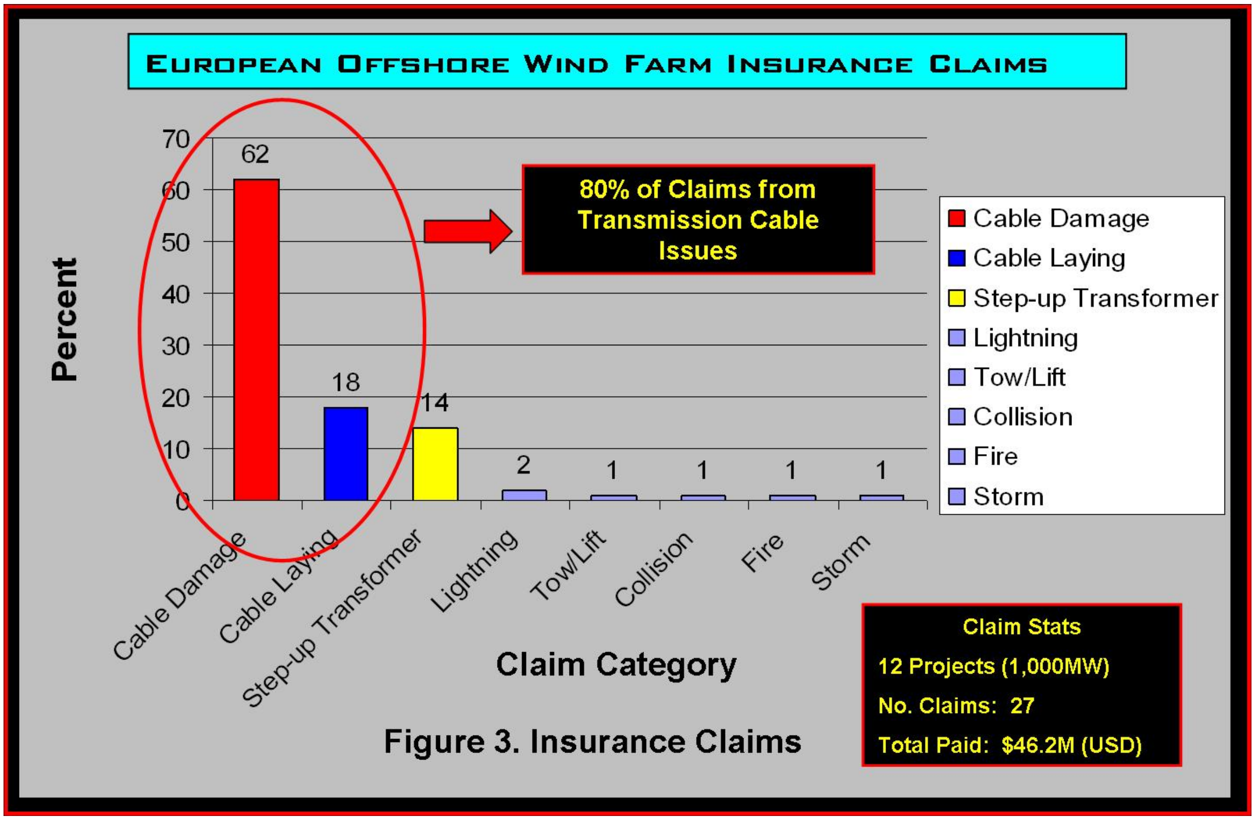


Figure 3. Insurance Claims

Sixty-two percent of the claims have come as a result of cable damage after installation and 18 percent of the claims came as a result of cable damage during the laying process. In total 80% of the claims came as a result of subsea cable issues. Note that the above figures do not include the claims associated with the turbines themselves. Many of the cable damage claims are the result of poor cable routing and substandard cable protection.

To date the industry has been focused on the issue of offshore turbines and the generation of power along with grid interconnection. However, when projects transition from on shore to offshore the challenges of operating in this harsh environment can make or break a project. Cable protection and safe cable route planning have been going on for decades in the subsea telecommunications and power industries. It is critical that developers understand the importance of effective, experience based planning very early in the project cycle.

## Budget Cycles

With regard to the offshore component, the budget evaluation process should begin in the Pre-feasibility Study phase. It is during this phase that it is important to identify any potential conditions which exceed the normal scope of operations and to identify the cost drivers within the offshore project elements. For instance, if the site being contemplated is the habitat for an endangered species or vegetation it might require Horizontal Directional Drilling (HDD) in order to bring the cable ashore. This situation could be a major cost driver and has to enter into the overall site evaluation process. The goal during the Prefeasibility Study is to identify any show stoppers and 'out of bounds' conditions for the sites being considered.

It is during the Feasibility Study that the budgeting process takes a definitive shape. As the Offshore Work Plan is formed, budget trade offs are run throughout the process to access the financial impact of potential decisions. It is important that the budgeting process consider all the ripple effects of a project decision. There will be times when higher budgets are acceptable in one portion of the job to reduce the overall budget or reduce risk. During this phase, the offshore budgeting process includes the identification of marine assets, cable installation and protection methods, support infrastructure and all other detailed elements that go into effective installation planning. This phase will include input from potential suppliers and the overall evaluation of the supply chain available to support the project. The impact of the offshore schedule to the project is also evaluated. This includes weather windows for operations, asset transit time and the delivery of systems needed to perform the installation as well as the delivery of the hardware to be installed.

## Market Assessment

Two major economic factors have converged to impact the offshore industry. The first is the drop in oil prices and the second is the worldwide financial crisis. While very few believed that the industry could sustain the peak oil prices ($147/barrel) there were only a few that predicted that the price would fall so low ($32/barrel). Oil prices have rebounded over the past several months. While still at a level where operations can be profitable the response to the lower price and the financial crisis has been a move to reduce costs including, in some instances, a reduction in exploration budgets, staff reductions, delaying project implementation and a commensurate reduction in contractor rates. The most significant reductions have occurred in shallow markets that are more directly coupled to the short term price of oil. While there have been, and will continue to be, some reductions in deep water developments this market segment is less susceptible to short term fluctuations because of the long term nature of the projects. The offshore oil and gas industry very much centers on drilling rig utilization. As a result the industry is currently experiencing several changes:

- There has been an increase in the withdrawal or postponement of rig requirements,
- An increase in the number of rig sublets being offered,
- For the first time in several years there are idle rigs with several now 'warm stacked', and
- A significant fall in rig utilization rates is driving down the day rates for support vessels.

For the first time in a long while there are slots opening in the shipyards and an increase in offerings by owners to sell yard slots. While the shipyards are still operating off a backlog and there is a significant amount of tonnage that will enter the market in the next couple of years, and overall the market is much softer than it was even six months ago. This creates an opportunity for ship conversions and refurbishments.

The Subsea Telecommunications market continues to operate off a strong backlog. In 2008 there were 14 new installation contracts announced for over 73,000 km of new cable. The industry is currently operating with approximately a two year backlog for installation. Industry forecasts project an increasing demand for additional bandwidth, but the impact of tighter credit and less capital for investment has yet to significantly impact the Telecom industry. There is a trend toward more stringent credit requirements, more solid return on investment margins, and in general financial institutions and investors are much more risk averse. So while the long term impact of the global crisis is still unknown, the short term operational tempo is projected to remain high. There will be opportunities for shorter term offshore projects that complement other marine projects but these will have to be tightly scheduled and well managed.

In summary, the projection for offshore industry assets is uncertain but there are opportunities for new projects to be slotted in ship yards coupled with the fact that marine asset availability is increasing overall. However, the impact of the financial crisis and the significant tightening of credit are still unknown. The increased volatility in the offshore oil & gas market will provide opportunities to wind farm developers to ease market uncertainty for vessel utilization and help promote confidence in investment markets for offshore wind farm project installation cost stabilization. The longer view will prevail as long as the basis of the investment strategy is strong.

## INSTALLATION PLANNING

Requirements for installation activities will vary depending on the type of turbine system to be installed. Wind farm generator installation requires use of marine assets that can handle and install the following:

1. Shore side facility to mobilize and stage all parts/pieces to be installed.
2. Vessel to store on deck and deploy all elements of the wind farm.
   a. Installation of the seabed foundations,
   b. Installation of tower transition pieces,
   c. Installation of Tower and turbine system, and
   d. Installation of the subsea cable stations, interconnections between the tower and the main transmission line to shore.

It is very likely that several different classes of vessels will be used to accomplish the installation tasks. Different vessels are suited for the installation of the foundations, the wind tower and turbine system, and the subsea transmission elements.

The primary piece of equipment for the installation contractor is crane hoisting capability to both lower objects to the seabed and hoist objects over 70 meters above the deck of the installation vessel.

**A2SEA OCV Installing Windmill**

It is essential that the most efficient method of installation be used. Trade-offs must be done to determine the best options. For instance, there may be specialty vessels that are configured to install the turbine systems but transit times and availability may dictate the use of less efficient methods that are more cost efficient. Jones Act considerations must be at the forefront of vessel planning.

In addition to lowering objects to the seabed, the installer should be capable of monitoring the placement of these objects on the seabed with either an ROV or divers. This can be provided by a separate vessel or performed from the installation vessel.

It is obvious from the insurance claim chart above (Figure 3) that one of the areas which the developers need to focus more attention on is the subsea cable. The failure of a major transmission line can be catastrophic to the Return on Investment and the long term viability of a project. Repairs are complicated and require the utilization of expensive marine assets which may not be readily available. In addition, if proper cable acquisition planning was not done the cable and connectors for repairs may not be readily available. Installation planning is critical to the success of the project.

## Life of Field Service Planning

Life of Field Service (LOFS) includes the maintenance, operational, repair and decommissioning of the project over its projected life. These elements need to be planned and accounted for during the budgeting process. Understanding the requirements for performing maintenance on a structure installed in an offshore environment is the first step in developing a planned maintenance program. If a vessel is required to support life cycle maintenance then factoring in the cost of an offshore support vessel is a key element. One of the determining factors in deciding which turbine system to purchase should be the level of maintenance required. There is not only a cost issue to maintaining an offshore wind system but also a personnel safety issue. While the offshore industry has made huge strides in developing safe personnel transfer it is still an inherently dangerous operation and should be minimized where possible, and streamlined where unavoidable. Wind turbine systems that have been designed and manufactured for the marine environment and make maximum utilization of low maintenance components, are the first choice. Maintenance issues which are trivial onshore become major operations offshore. For instance, to clean the blades of an onshore wind turbine is relatively easy and straight forward. However, when it comes to either manually or robotically cleaning the blades of an offshore system the challenges grow exponentially in comparison.

Maintenance cycles can be established and a plan developed for each turbine system. However, the maintenance becomes more challenging when repairs are required. This may necessitate shutting down the turbine for extended periods of time until conditions are favorable for repair. Favorable conditions not only include environmental conditions but may also include waiting until the volume of work required in the field justifies mobilizing a vessel. Operators only make money when the turbine is generating so it is critical that maintenance and repair issues be considered in the purchase decision.

As the oil and gas industry have learned, decommissioning costs are not trivial, especially when they involve large structures offshore. These costs must be accounted for in the budgeting process and reserves should be taken through the life of the field to ensure that the funds are available for decommissioning of the installed system.

## CONCLUSIONS

1. Understanding and quantifying the dynamic nature of cost risk in the offshore work environment is critical to realizing the projected Return on Investment (ROI) of an offshore wind project.
2. Effective site engineering, component selection, planned maintenance and front end planning is critical in minimizing offshore installation and LOFS costs.
3. Offshore planning and engineering should begin in the Prefeasibility Study phase and should include the input of experienced offshore professionals.
4. Risk identification and mitigation planning is key to a successful offshore project.
5. Fluctuations in the Offshore Oil and Gas industry will have significant influence on the cost and availability of offshore assets and resources for use in the offshore wind industry. Volatility in the energy markets can influence both revenues and operating costs.

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