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Abstract

Technologies are changing fast, and opening for business opportunities. It is difficult for individual companies to keep track of these changes and how they apply.

In this master thesis, a systematic approach has been used to identify and evaluate innovation opportunities in operations and maintenance of an offshore wind farm. Several opportunities were identified and evaluated. The evaluation process emphasized the identified opportunities’ ability to solve industry problems and ability to generate profit.

The evaluation process concluded that an autonomous drone product and a predictive maintenance service were the most promising innovation opportunities. Business model canvas was used to show how a business could be built around the opportunities.

Acknowledgements

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List of Abbreviations

AI	Artificial intelligence
CAD	Computer-aided design
FEED	Front end engineering design
IOT	Internet of things
LCOE	Levelized cost of energy
Lidar	Light detection and ranging
OEM	Original equipment manufacturer
OFTO	Offshore transmission owner
O&M	Operations and maintenance
ROV	Remotely operated vehicle
SCADA	Supervisory control and data acquisition
TLP	Tension leg platform
UAV	Unmanned Aerial Vehicle

1 Introduction

1.1 Background

In recent years, we have seen a rapid technological development, surpassing every linear projections previously made. Automatization, cloud computing, internet of things (IoT), autonomous cars and artificial intelligence are just some of the buzzwords and terms that have emerged because of the technological developments.

What we are part of have been called “the digital transformation”, and it is estimated to have a huge impact on both business and society. Chat-bots are providing autonomous customer service, houses are being 3D printed and drones are conducting inspections in harsh and dangerous environments. Companies are spending billions on digitalization, and just in Spain, 93% of companies have developed a digital strategy. (BBVA, 2018).

Smarter, better and more efficiently run businesses are observed as results of successful exploitation of these changes. Yet, a recent study found the technological and digital advances to be the biggest challenge facing tomorrows business leaders (Morrison, 2017). Simply put, the changes are so rapid, it’s hard to keep track and see how the changes apply.

1.2 Objective

The objective of the thesis was to show how a systematic approach can be applied in an industrial context, to identify and evaluate innovation opportunities emerging from trends in technology development.

1.3 Research Approach

The research included literature, attending conferences and webinars, visiting a wind farm, and interviews with people with knowledge of the industry and thesis-related topics, to learn more about offshore wind, operations and maintenance, and the main challenges in the industry.

Weekly meetings have been held by the supervisors, where trends in technology and business developments have been lectured and discussed, in addition to workshops and discussions related to the identification and evaluation process.

1.4 Structure of report

This thesis consist of six chapters, a bibliography and an appendix. After this, the introduction chapter, the following chapters make up the rest of the thesis:

Chapter 2 provides the industrial basis for the thesis. An assessment of status and outlook for the offshore wind industry is provided, in addition to the parts of an offshore wind farm, operations and maintenance in the industry, and a presentation of the main challenges.

Chapter 3 give insights to the development in technology trends that is observed in recent years. In addition, innovation is defined and ways of protecting intellectual property rights are presented.

Chapter 4 is the part of the thesis where the methodology is explained, and the innovation opportunities are presented and evaluated.

Chapter 5 covers a discussion on the method used, the work done, and the findings.

Chapter 6 concludes on the systematic approach, highlights the main findings in the thesis, and give suggestions for further work on identification and evaluation of innovation opportunities

1.5 Limitations

The purpose of the thesis was to show how a systematic approach could be used to identify and evaluate innovation opportunities emerging from trends in technology development. The research behind the identification and evaluation process was limited what was seen as suitable for carrying out the purpose .

2 Offshore wind

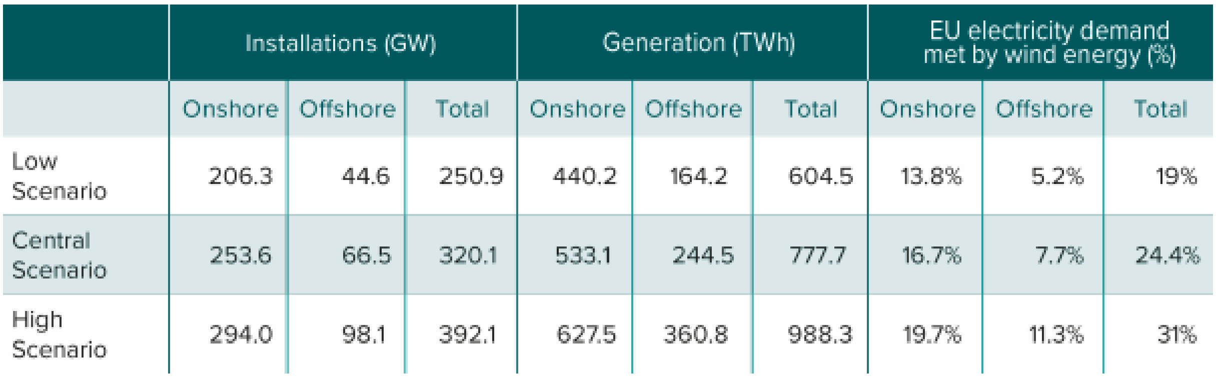
2.1 Status and outlook

Commercial offshore wind farms have been built in large scale in recent years, but the offshore part of the wind power industry have only existed for 27 years. In 1991, the Vindeby offshore wind farm started operations outside of Denmark. As of 2017, the worldwide installed capacity amassed 14 gigawatts, 90% of was located in European waters (Pee et al., 2017). From WindEurope´s annual report for 2017, it was a record year for new installations. Wind power accounts for 11.6% of Europe's electricity demand, about 90% of that is onshore wind power. The rest, slightly more than 10%, is offshore wind power. (WindEurope, 2018).

The offshore wind industry has seen a rapid fall in levelized cost of energy (LCOE) in recent years but the industry is still highly dependent on government subsidies. This is about to change, the Swedish company Vattenfall won a contract for building what will be the first ever subsidy-free offshore wind farm, estimated to be producing electricity within 2023. The drivers behind these rapid developments can largely be broken down to increased turbine size and efficiency gains as the industry has matured. (Hovland, 2018).

In IEA´s World Energy Outlook Report 2017 (IEA, 2017), the share of renewables in power production is estimated to account for 40% of the global production by 2030. The scenario worked out in the report also estimates that wind power will become the largest provider of electricity in the European union after 2030. The industry has matured the most in Europe, but developments are also seen in other parts of the world. The US, for instance, has a technical potential of power production from wind power being twice their current electricity demand, but a number of issues, like financing, supply chain, lack of a stable market, uncertain timeline of permitting, etc. are identified in (Mone et al., 2017) as barriers to increase the slow adoption currently being observed.

Just recently, member states of the European parliament voted for a legally binding target that 50% of all electricity demand in the EU should come from renewables and wind power will play a big part in reaching this goal (Schiermeier, 2018). An estimation with 3 scenarios for electricity production by wind power is shown below.



	Installations (GW)			Generation (TWh)			EU electricity demand met by wind energy (%)		
	Onshore	Offshore	Total	Onshore	Offshore	Total	Onshore	Offshore	Total
Low Scenario	206.3	44.6	250.9	440.2	164.2	604.5	13.8%	5.2%	19%
Central Scenario	253.6	66.5	320.1	533.1	244.5	777.7	16.7%	7.7%	24.4%
High Scenario	294.0	98.1	392.1	627.5	360.8	988.3	19.7%	11.3%	31%

Figure 1 European wind energy association (EWEA) forecast for Wind power production by 2030.

Operating conditions for offshore wind farms are far more challenging but are also providing better opportunities for production than onshore. Even though the costs of projects offshore can be 40% more expensive than onshore, large investments are being made, to further develop the industry (Pee et al., 2017). Especially deeper waters (>60m) have a huge, unlocked, potential, accounting for about 80% of the wind resources. The deeper waters in Europe have the potential of meeting the European demand for electricity 4 times, but developments in this segment are still very uncertain.(Buddensiek, 2018).

The first floating wind farm didn´t exists before very recently, when Statoil´s Hywind Scotland floating wind farm was commissioned in October 2017. Despite the high uncertainties involved, Statoil has ambitious plans, aiming for a LCOE of 40-60 €/MWh by 2030. Knowing the enormous potential for floating solutions, and drawing from deep knowledge of operating in harsh offshore conditions, Statoil has taken the first step in a promising industry that can take a big part of the future energy mix. (Buddensiek, 2018).

2.2 Main stakeholders

In offshore wind, there are three major stakeholders; Owners, Wind turbine Manufacturers and Offshore transmission owners. These three groups carry the responsibility of the overall wind farm. There are several ways to divide the responsibilities dependent on owner´s desires, but wind turbine manufacturers are always involved in turbine maintenance to some degree, at least the first years of operation (Hassan, 2013). Some of the largest companies in each stakeholder group are listed below:

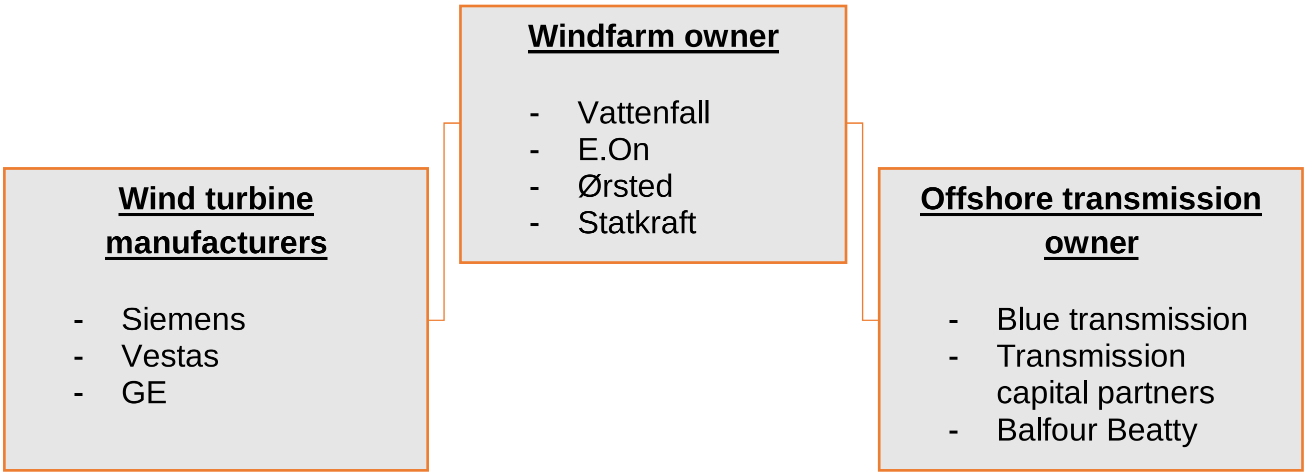


Figure 2 main stakeholders groups and actors in UK offshore wind. (Hassan, 2013).

2.3 Offshore Windfarm

An offshore windfarm consists of several wind turbines located in the same area, producing electricity by harnessing wind energy. In a large wind farm, several hundred turbines can be grouped together. Each turbine consist of the structural parts, foundation and tower, the turbine, and the blades. The turbines are connected to electrical equipment and infrastructure for transmission of electricity to the grid, and control and data acquisition. (Thomsen, 2014).

2.3.1 Site selection

When a site for an offshore wind farm is to be selected, a number of considerations have to be taken. Some of the important ones are wind conditions on-site, water depth, seabed conditions, distance to shore and O&M ports, government regulations, as well as the economics and feasibility of installation of infrastructure and turbines at the considered site. (BVG-Associates, 2010).

2.3.2 Structural

Foundation

In offshore wind farms, there are different foundation concepts available. The concept selection is dependent on a variety of parameters, the main ones being: water depth, seabed condition and weather conditions on-site. The foundation concepts can be categorized into either fixed or floating foundations.

Fixed-bottom options:

- Monopile
- Tripod
- Jacket
- Gravity based foundation/structure
- Suction Caisson

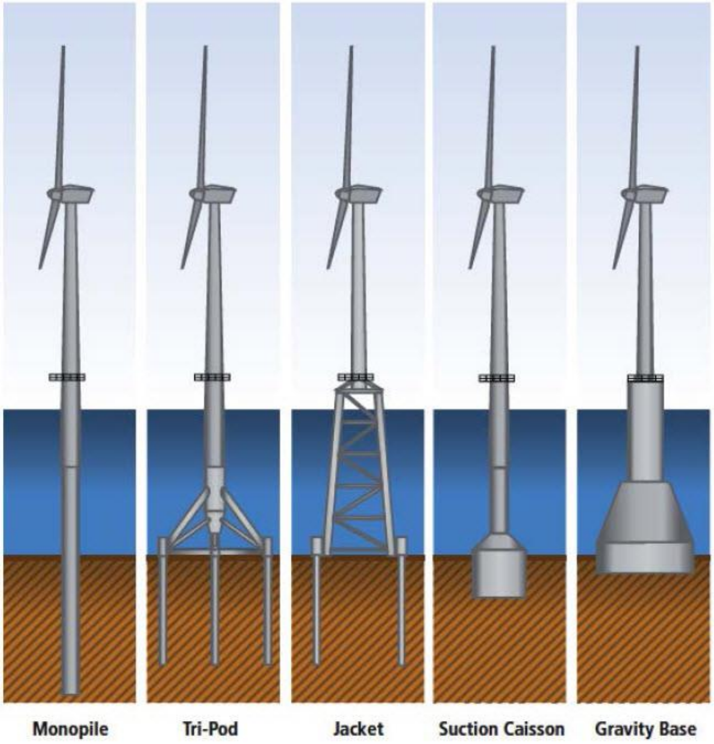


Figure 3 fixed-bottom concepts. (Augustine et al., 2012).

Monopiles (79%), Tripod (14%) and Jacket (6%) accounts for almost all fixed bottom solutions seen today (PEYRARD, 2015). The fixed concepts are limited to a water depth of approximately 60 meter. Monopiles are typically used in water depths to 30 meters, and jackets or tripods are used in the 30-60 meter water depth interval. (Bhattacharya, 2017).

Floating options:

- Spar
- Semi-submersible
- Barge
- Tension-leg platform (TLP)

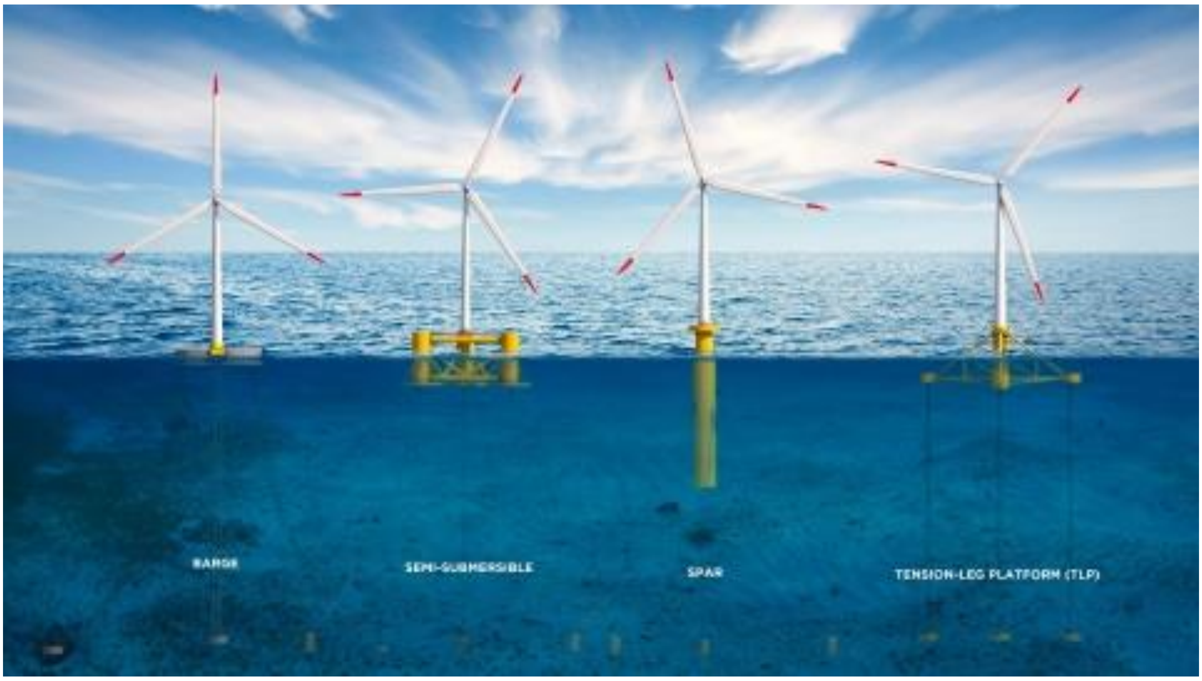


Figure 4 floating offshore wind foundation concepts. (Guzzetti, 2017).

The four different floating wind concepts are illustrated in the picture above. The Barge, Semi-Submersible and the Spar, all requires either buoyancy or ballast for stabilization, and they are connected to the seabed through mooring lines and anchors. The TLP is instead moored by tethers, which results in a more complex installation procedure, but allows the structure to consist of a lighter substructure. Encouraging developments are seen in all the above mentioned concepts, although Statoil´s Spar solution (Hywind) is the only one with commercial operations this far. (Guzzetti, 2017).

Tower

The tower is a tubular structure usually made of steel, connecting the foundation to the nacelle, blades and the rotor. Cables for electricity transmission and for control and communication purposes goes through the tower and up to the turbine. Stairs and/or an elevator on the inside of the tower allows technicians to access the nacelle. (Thomsen, 2014).

2.3.3 Turbine

The wind turbine is the part responsible for converting kinetic energy in the wind to electrical energy. The turbine is composed of the nacelle, the rotor and the blades. The nacelle is located on top of the tower and is able to rotate around a vertical axis thanks to the yaw system, which orients the nacelle for the rotor to directly face the wind direction. Inside the nacelle is the drivetrain (shaft, gearbox and generator), that converts blade motion to electrical power. (BVG-Associates, 2010)

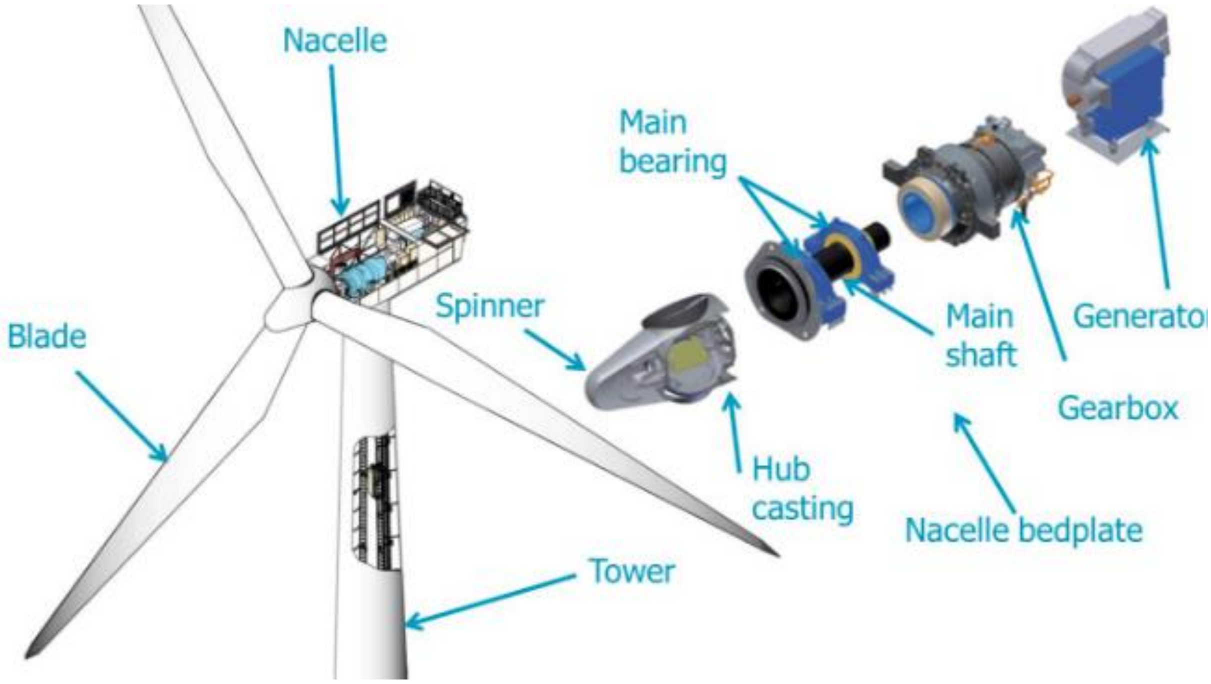


Figure 5 turbine components. (kentwindenergy, 2018).

2.3.4 Electrical transmission system

The electrical system is composed of onshore substation, offshore substation, export cables and array cables. Each turbine is connected to the offshore substation by array cables. The offshore substation receives power from the turbines and increases the voltage of the power from the turbines, to reduce electrical losses during export to the onshore substation. The onshore and offshore substation is connected by the export cables. The onshore substation receives power from the offshore substation, and transforms the power into grid-voltage, before transmitting it to the grid.(BVG-Associates, 2010). The setup and relationship described is illustrated in the picture below.

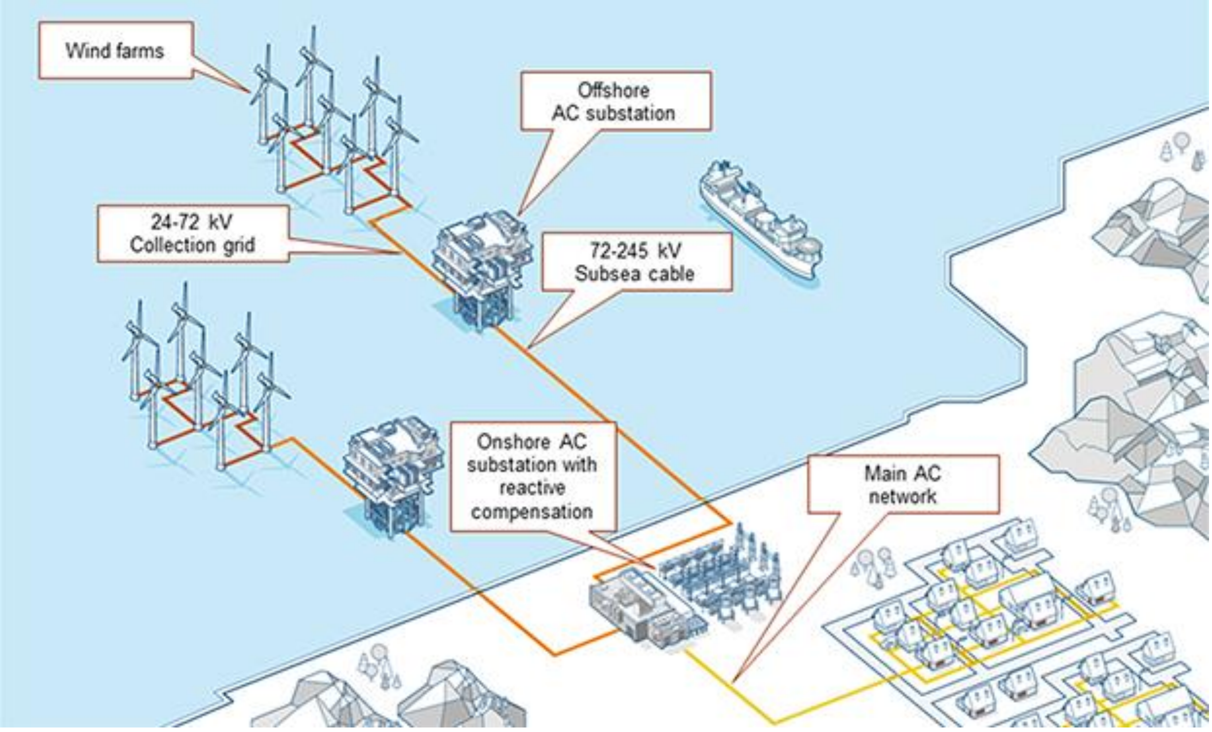


Figure 6 offshore substation, cables and connection to grid. (ABB, 2013).

2.3.5 Turbulence and Wake effect

Turbulence

Turbulence in relation to wind refers to irregular behavior in the energy distribution of the wind, as opposed to laminar distribution. Turbulence has implications on the loads experienced by the wind turbine. Understanding and monitoring of turbulence is therefore important, i.e. to avoid fatigue of the blades.

Wake effect

A wind turbine harness the kinetic energy in the wind. When wind causes the turbine blades to rotate, the speed and direction of the wind changes, this is called wake effect. In the context of a wind farm, wake effects created by one turbine, can therefore have an effect on the wind direction and speed experienced by other turbines in the wind farm. (Delft, 2018).

Figure 7 wake created by turbines. (Carbon-Trust, 2017).

2.4 Wind farm lifecycle

The lifecycle of an offshore wind farm can be split into 5 different phases, as illustrated in the picture below. The planning & development phase consists of surveys on the environment, metrological conditions, seabed conditions, in addition to development surveys (feasibility, licensing, etc.) and FEED studies. Substructure installation covers installation of everything below sea-level, such as cables and foundation. Installation & commissioning covers the installation and commissioning of the turbine. (Thomsen, 2014).

The operations and maintenance phase is the focus of this thesis, and will be covered more thoroughly in the following parts. Decommissioning of offshore wind turbines lack a standard frame, as the industry is still far from matured. The first windfarm, Vindeby, was just recently decommissioned, which shows how underdeveloped this phase still is (**Martin**, 2017). Another choice is to repower the turbines, a choice that may be beneficial, due to the rapid developments in turbine technology.

Figure 8 stages in the lifecycle of an offshore windfarm. (Ulstein, 2016).

2.5 Operations and Maintenance

Operations and Maintenance of offshore wind farms refers to every activity that occurs after commissioning and before decommissioning or repowering. This is the longest phase in the lifetime of an windfarm. It accounts for approximately 24% of the total cost of through the lifetime of an offshore wind farms. (Hassan, 2013).

According to (Newman, 2015), operations are the “day-to-day activities that cover the high level control and management of the wind farm such as remote monitoring, contracting of port facility, crew transfer vessel hire and electricity sales”, while maintenance is “repair and service of the wind farm and is split into scheduled preventative maintenance and unscheduled corrective maintenance”.

2.5.1 Key activities

The key activities in operations and maintenance have been categorized and described in (Hassan, 2013), and goes as follows:

- Onshore logistics and Offshore logistics

Onshore logistics are concerned with port facilities, warehousing of spare parts, office space, bunkering solutions and so on.

Due to the nature of offshore wind power, offshore logistics are an important part of O&M. it concerns the coordination of the various vessel types, small transfer vessels to large jack up´s, carrying crews, equipment and spare parts. During the operations and maintenance phase in an offshore wind farms lifecycle, multiple activities may take place simultaneously, so managing offshore logistics optimally is key.(Hassan, 2013)

- Turbine maintenance

Turbine maintenance can be divided into scheduled, preventive maintenance, and unscheduled, corrective maintenance. The issues with the traditional approaches to maintenance has been that maintenance is done either when it’s not needed, or too late, resulting in suboptimal performance and unnecessary use of resources. A strategy that has gained momentum in several industries is condition-based maintenance, which uses information about equipment condition to determine when maintenance is needed. Condition-based maintenance has gained momentum in offshore wind in recent years but still holds a significant unused potential. (Fischer and Coronado, 2015).

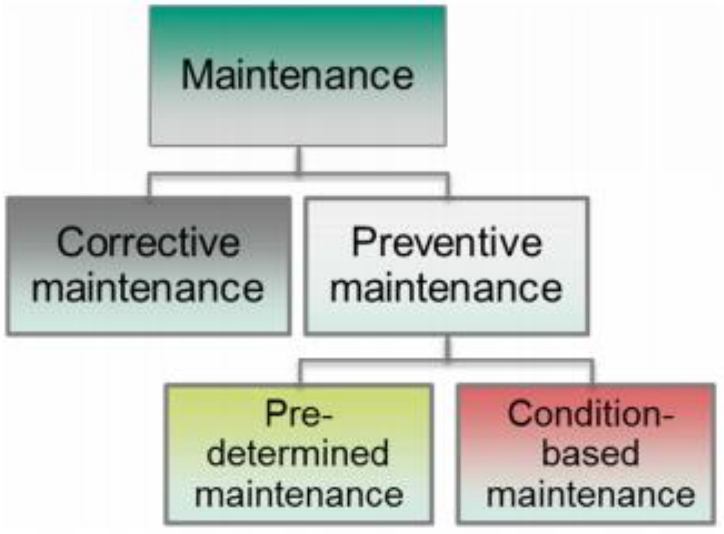


Figure 9 maintenance strategies. (Fischer and Coronado, 2015).

- Export cable and grid connection

This activity comprises what is done with regards to onshore and offshore substations and the export cables, and is the offshore transmission owner´s responsibility. Typical activities are repairs and inspections.(Hassan, 2013)

- Array cable maintenance

Monitoring, surveying and repairing damaged array cables are the main responsibilities the owner has with regard to array cable maintenance. Movements of cables and exposure to tides and sediments are common issues.(Hassan, 2013).

- Foundation maintenance

Activities related to foundation is mainly visual inspections and surveys, to ensure that scour and corrosion protection is sufficient and that climbing, lifting and similar activities can be conducted safely. (Hassan, 2013).

- Back office, administration and operations

Work related to the overall management of the wind farm, for example planning, coordination, production management, support, etc. (Hassan, 2013)

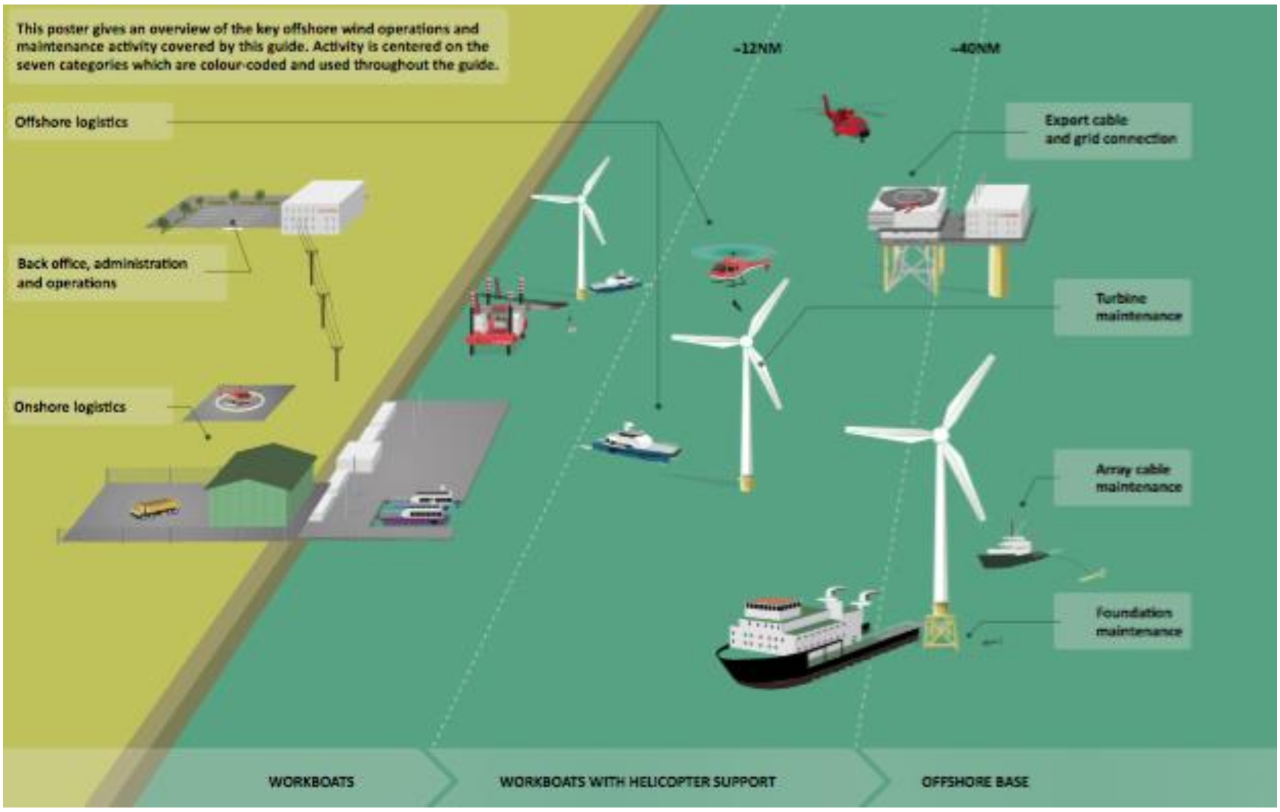


Figure 10 overview of key O&M activities. (Hassan, 2013).

2.5.2 SCADA

SCADA is an abbreviation of supervisory control and data acquisition, which is a control system architecture. SCADA is used by operators in offshore wind for remote control and surveillance of operational data. The exact configuration and information obtainable from this kind of system depends on the supplier. (Fischer and Coronado, 2015) states that almost every wind power operator have some kind of SCADA system and that the minimum of data obtainable by such system is typically the following:

- “Wind speed
- Wind direction
- Active power
- Reactive power
- Pitch angle
- Rotational speed (rotor and/or generator)”.

2.5.3 Condition monitoring system

Condition monitoring is simply the process of assessing the condition of an asset or components of that asset. The term comprises real-time sensor data, as well as inspections, NDT testing and other techniques used in condition assessments. Online condition monitoring systems, meaning real-time condition data from sensors, have become more common in offshore wind in recent years, typically providing information on vibrations, temperature and oil quality. In predictive maintenance (also called condition-based maintenance), condition monitoring data is used to predict failures. (Fischer and Coronado, 2015)

2.5.4 Yaw and Pitch control system

The yaw system consist of motors, gearboxes, breaks and sensors, and is located around the bearing connecting the nacelle and the tower. The yaw systems task is to orient the rotor towards the wind direction. (BVG-Associates, 2010).

Power output is controlled by the pitch system, which controls the angle of the blades. This system can either be hydraulic or electric, which both serves the purpose of holding the blades in a specific angular position for controlling power output, minimize loads or performing start/stops. (BVG-Associates, 2010)

2.5.5 Warranty

Warranties hold an important role in operations and maintenance in offshore, especially warranties on wind turbines provided by original equipment manufacturers (OEMs). Wind turbines usually comes with an initial warranty for five years, in which a certain level of availability is guaranteed. OEMs will therefore have day-to-day responsibilities for the maintenance of turbines. After the initial 5 years, the owners mainly have 3 choices; renewing maintenance contract with OEM, develop in-house expertise or outsourcing to a third party. The offshore wind industry still not considered a very mature industry, and it is only in recent years that turbines have come out of warranty in larger scale, confronting owners the choice of maintenance responsibilities. Some operators are looking to others than the OEM for this responsibility, as they feel this could increase their profitability. (Hassan, 2013).

2.5.6 Challenges

Some of the main challenges in operations and maintenance of offshore wind farms have been identified and are described below:

- Access

Access to wind turbines are one of the biggest challenges in the industry, due to challenging weather conditions. Remote access, new vessel concepts and new access systems have been identified by (Newman, 2015) as ways to cope with this challenge.

- Reliability and availability

A report covering statistics from several offshore wind farms found that availability in these were only 80,2%, compared to a typical figures of above 95% in onshore windfarms. The difference in availability was mainly caused by gearbox and generator failures and the duration for repairs/replacements. (Dinwoodie, 2017).

Unscheduled maintenance, which is reactive maintenance due to unexpected failures, accounts for around 65% of O&M costs. This number is far higher than what would be acceptable in more mature industries. Advanced condition monitoring techniques and smarter use of data are areas which can improve reliability and availability.(Newman, 2015).

- Logistics and vessel costs

Logistics and vessel costs are closely related to the two challenges listed above. Unexpected failures may force owners to charter vessels and mobilized crews and other resources on short notice. Also, a strong dependence on favorable weather conditions for access to turbines and transportation of resources needed in offshore operations, the result is significant amounts of downtime causing lost production. (Salomonsen, 2015).

The figure below gives a good indication of the cost drivers in O&M. Lost revenue due to unwanted downtime, and vessel costs make up most of the total cost, and needs to be addressed. Increased predictability of failures will reduce downtime and allow planning of multiple operations to be performed when weather conditions are favorable. Further developments in remote operations have also been identified to drastically reduce the vessel costs. (Newman, 2015).

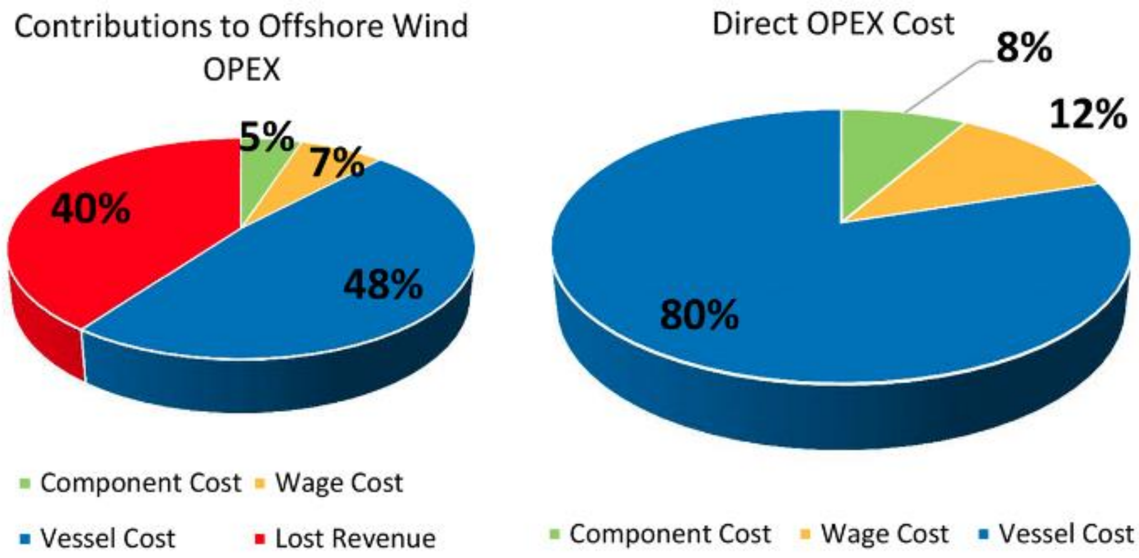


Figure 11 O&M cost components. (Dinwoodie, 2017).

3 Innovation and technology trends

The business world is not how it used to be, physical assets like plants, buildings and machines are not the dominating assets they used to be. Looking at Google, Facebook, Airbnb and Uber, they are some of the largest companies in the world, not because of their physical assets but because of the platforms they are offering. They are part of a larger transition, called the digital transformation. Computer capabilities have also outperformed humans in task that we could not imagine before, caused by development in artificial intelligence. (McAfee and Brynjolfsson, 2017).

In a digital world, intellectual property right become more important, which is illustrated by companies in the S&P 500 index of the US stock market, where 80% of businesses market value was related to physical asset in 1975, while the same tally only accounted for 20% of the market value in 2005 and have only increased in following years. (Yi, 2012).

3.1 Innovation

There are many ways to define innovation, but the definition given by (Maranville, 1992), which states that innovation is: “application of better solutions that meet new requirements, unarticulated needs, or existing market needs” is seen as suitable in the context of this thesis.

3.2 Technology trends

According to (Bang and Tauqeer, 2018), modern day technology trends can broadly be divided into connectivity, autonomization, sensorization and digitalization. Drivers of these trends are observed to be changes in energy and materials/hardware. Storage capacity of energy has increased, while cost of hardware and materials have dropped significantly. Also, data storage and processing capacity have both increased exponentially.The effect of these changes are:

1. “Cheaper hardware has enabled the possibility of installing sensors to and equipment or gadget.

2. Grid independent solutions of energy (solar panels, large battery storages etc.), hardware (fiber optics, 4G etc.) and sensors (GPS, Lidar, RFID etc.) have connected devices, equipment, systems and units.

3. Connectivity of things and smart sensors have helped digitalization.

4. Digitalization, Sensorization and different materials/hardware have helped achieving automation”

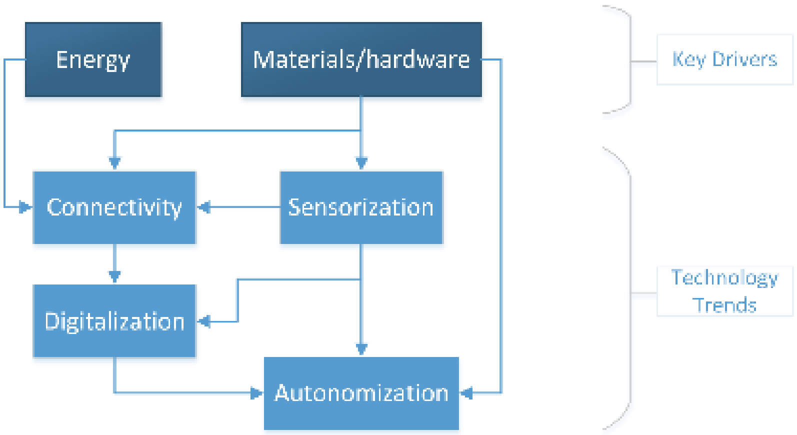


Figure 12 key drivers of modern technology trends. (Bang and Tauqeer, 2018).

Some terms and buzzwords that has arrived in the wake of the developments in technology trends are explained below:

Internet of things (IOT): Internet of things refer to physical devices connected to the internet. The reason this term has emerged is the increasingly amount of devices that has connective capabilities. What was earlier only limited to devices like cellphones and computers, have now spread to watches, coffee machines, sensors and a huge amount of other devices. One estimation states that by 2020, there will be over 26 billion connected devices. (Morgan, 2014).

Additive Manufacturing: Additive Manufacturing is a technique where material is added layer by layer to create a product in 3D. Typically, the part/product to be produced would be created on a computer, and created by a computer-controlled process where the material is added layer upon layer, differing from other manufacturing processes that removes material. Thus, additive manufacturing provide advantages over traditional manufacturing in terms of reduced material waste and lighter products. Manufacturing times can also be reduced drastically, and products that were previously composed of several parts can be produced in one, increasing strength and durability. (GE, 2018a).

Additive manufacturing became popular with the use of 3D printers to created plastic parts. This is now widely used in prototyping. Other technologies also exists, allowing products made up of various metals, ceramics and biochemicals to be produced by additive manufacturing. Aerospace, automotive and health care product manufacturers have already made use of additive manufacturing, significantly reducing lead times, without compromising quality.(GE, 2018a).

Cloud computing: Amazon defines cloud computing as: “The on-demand delivery of compute power, database storage, applications, and other IT resources through a cloud services platform via the internet with pay-as-you-go pricing”.

Cloud computing provides external applications, storage and processing capacity, enabling accessibility for users regardless of location, only dependent on internet access. For businesses, this enables increased and faster sharing of digital resources and reduced capital expenditure. It also enables real-time monitoring of assets in remote locations.

Figure 13 cloud computing connecting devices to shared resources. (GOVERNOR-BUSINESS-SOLUTIONS, 2014).

Autonomization: Making something autonomous, meaning giving a device or a machine the ability to act intelligently and respond to information. An autonomous car for example, uses its sensors to get information on the surroundings and continuously make decisions to ensure that the passengers gets transported to their destination in a safe and efficient way. (Dokic et al., 2015).

Artificial Intelligence: Artificial intelligence is a term used to describe a machine´s approach on using human-like cognitive processing. Machines with artificial intelligence can use situational information for cognitive tasks like learning, thereof the term machine learning, planning and problem solving. Real world examples of artificial intelligence is natural language processing, machines playing strategic games like Go and Chess, and autonomous cars, which have to make decisions based on numerous inputs and considerations (Russell and Norvig, 2016).

Achieving artificial intelligence is complex, and draws on different tools, depending on desired function. Bayesian networks are useful for a number of functions, for example the Bayesian inference algorithm used in reasoning and the expectation-maximization algorithm used in learning (Russell and Norvig, 2016). Essentially, artificial intelligence is a construction of algorithms that converts input data to knowledge, solutions, etc.

Other tools include artificial neural network, which are based on how human neural networks in the brain function. The artificial neural networks consists of layers that responds differently to the same input. The functionality of these networks are so that they don't necessarily require any prior knowledge, for example in image recognition, use cases with artificial neural networks make it possible for it to identify cats in images, only based on a manual cat or no cat labeling in example images.(Clark, 2012).

Predictive Analytics: Predictive analytics is a term that describes the use of analytical and statistical methods to develop models that predict future events or behavior (Nyce and CPCU, 2007). According to IBM, "Predictive analytics brings together advanced analytics capabilities spanning ad-hoc statistical analysis, predictive modeling, data mining, text analytics, optimization, real-time scoring and machine learning". With these tools, predictive analytics are used to identify patterns and give predications of future events and/or behavior. Predictive analytics have many applications, i.e. credit scoring, predictive maintenance and customer relationship management. (McKendrick, 2012).

Blockchain technology: Blockchain technology is a technology for keeping record of information. Usually, recordkeeping is centralized, and banks, brokers and governments store information at centralized offices and/or servers. This is not the case when using blockchain technology, which uses what is called a distributed ledger technology. As information added is verified by participants in a network, it is added in blocks that are sorted in chronological order, and is visible in the ledger for the participants of the network. Every new block is linked to the former, and added by the use of cryptography, ensuring security of the blockchain. (Investopedia, 2018).

The blockchain technology is important, because it gives participants security and visibility of information. The technology could have a huge influence on several business processes, and could potentially remove the need for third parties like banks, brokers and governments. Smart contracts and recordkeeping of transactions allows parties to trade and make agreements directly with each other, without involving external parties. The contracts and/or the transactions can be made visible in the ledger for other relevant stakeholders like border control or other authorities that require visibility. (Investopedia, 2018).

UAV: Unmanned aerial vehicles (UAVs) are part of the category Unmanned Aerial Systems (UASs), and is used to describe the likes of drones, which operate without a human pilot on board. These vehicles have various degrees of autonomy, some are controlled by operators by remote controllers, and some have more autonomy, controlled by onboard computers. (Cir, 2011).

Augmented reality: Augmented reality (AR) is a technology where a computer generates extended perceptual information in addition to how humans see the physical world. AR differs from virtual reality, in that it combines the real world with computer generated conceptions. Augmented reality has many applications, ranging from pure entertainment, like gaming, to visualization in shopping, education and training, to name a few. (Anna, 2018).

Big data: Big data is a modern term used to describe datasets that are too big to be used in traditional analytics. Big data can be characterized by volume, velocity and variety. Today, we have so many sources that create new data, that the volume available are enormous, and they are transferred fast from sensors or other devices capturing data. Lastly, data comes in different forms and patterns, structured, unstructured, continuous and sporadically. Traditionally, these datasets could not be handled by traditional methods but due to the advance of predictive analytics, big data is invaluable for today’s biggest companies, like Apple, Amazon and Google. (SAS, 2018).

Digital twin: A digital twin is simply a virtual replica of something in the physical world. The digital twin can both be a representation of a physical asset, or a system of several assets that function together. Input data from sensors or other measurement technologies are used to monitor the condition in real-time and continuously learn more about the product/system behavior by application of machine learning techniques. The digital twin provides numerous benefits due to its ability in terms of monitoring, prediction, simulation, visualization and many other use cases. Digital twins are already creating value for industrial purposes, its used in automobile testing, detection of bottlenecks in manufacturing, simulation of marine operations, etc. (Rajput, 2018).

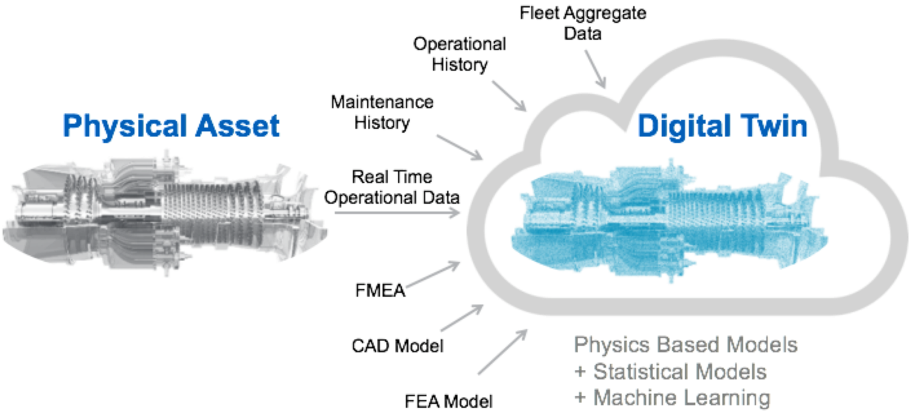


Figure 14 illustration of the inputs to a digital twin. (Rajput, 2018).

3.3 Intellectual property rights

Intellectual property rights refers to the rights of using plans, ideas or other intangible formats of creations that belongs to a person or a firm. Such rights can take different forms, such as patents, copyright, trademark or trade secret. These rights incentivises innovation and lets the creator(s) have exclusive rights to their ideas, for a limited time. (Businessdictionary, 2018).

Table 1 ways to protect intellectual property. (Gulick-Law, 2018).

Patent	Protects an invention by excluding others to make use of, or selling the invention.
Copyright	A form of protection given to authors and artist, to protect a literary, musical and similar works.
Trademark	A trademark is word, symbol or similar expressions that is used to identify the source of a product.
Trade secret	Know-how, methods or receipts used by a company and kept secret to avoid copying.

The above mentioned concepts are four common ways for protecting intellectual property. However, experience has shown that protection against competition is very hard, and companies usually needs to do more to protect their products and services. (Brown, 2014) draws on 30 years of experience with entrepreneurs, and have found that successful ones cooperates closely with important customers, and try to fill their needs as fast as possible.

4 Identification and evaluation of innovation opportunities

4.1 Methodology

The methodology used to identify and evaluate the innovation opportunities consisted of a 4-step process:

1. Identification of opportunities
2. Initial screening - Evaluate ability to solve a problem
3. Opportunity screening - Evaluate ability to generate profit
4. Present the best opportunities in a business model canvas

4.2 Identification of opportunities

To get a better understanding of operations and maintenance in offshore wind farms, and how technology trends apply, a structured breakdown method of services, products and was used, followed by a method for breaking down the effects of relevant technology trends on the selected services, products and processes.

The sheets used were developed by the supervisors, and can be found in the appendix. The identified innovation opportunities were found during workshops using the sheets described above, in combination with the research that was conducted.

4.3 Initial screening

This is the first part of the evaluation process. The main purpose of the selected screening criteria in the initial screening is to evaluate and document if the identified innovation opportunities have the ability to solve industry problem(s). The criteria are listed below and explained further:

Table 2 explanation of screening criteria for the initial screening.

Screening criteria	**Description of criteria**
Background	Relevant background information regarding the opportunities, technology and/or research is presented.
Problem(s)	The industry problem(s) that the innovation opportunity is attempting to solve will be described here.
Existing solution(s)	A description on how the problem(s) is currently managed by the industry. A complete list of existing solutions would be difficult to obtain, but the aim is to present some existing solutions.
Description of idea	A brief description of the idea behind the innovation opportunity.
Function	An example of how the service/product can be used.
Product/Service quality	The quality is determined based on how well the product/service can solve the problem(s), compared to competitors.
Problem size	The problem size is determined based on the how real the problem is, and if there is a market for the problem.

4.3.1 Electricity storage

Figure 15 500 MW battery facility. (ROSELUND).

Background

The cost of batteries has traditionally been very high, combined with limited capacities and large size. In recent years, this has changed, as off the grid solutions and the electrical car industry has gained momentum. Batteries are now becoming more and more capable, thanks increased demand from several industries. (Williams, 2018).

A report from the Carbon Trust found that an optimized storage solution in the UK electricity system could save average yearly electricity bills 50£ or total system savings of 2.4£Bn per year by 2030.(Lever et al., 2016)

Problem

Renewable energy like wind and solar are dependent on specific metrological conditions for production of electricity, making it an unreliable source of electricity, requiring electricity to also be produced from fossil sources. (Coren, 2016).

From a consumer point of view, its desirable that electricity producers can provide reliable amount of energy to reduce peak prices in the winter months. (Deign, 2018a).

Overproduction of electricity is a problem that occurs in some countries from time to time, sometimes resulting in consumers getting paid to use electricity (Coren, 2016).

Existing solution(s)

Common solutions today are variations of direct transmission to the grid, without the possibility of storage. (Sørensen, 2016).

Description of idea

The idea is to install batteries, giving operators the opportunity to store electricity when the grid-demand is low, and sell more electricity when the demand is high.

Function

The system will use optimization algorithms to decide how much electricity is stored in batteries and how much is transmitted to the grid. The algorithms shall balance storage capacity, grid demand and stability and offshore wind conditions, to make the most out of favourable production conditions for the turbines and electricity prices.

Product quality

This solution is unique compared to existing solutions.

Problem size

This ranks as a problem someone is willing to pay for. It is clearly interesting for companies in the industry, and some are looking at concrete solutions. Statoil have already developed a pilot project on battery storage that will launch in the autumn of 2018. (Statoil, 2017).

4.3.2 Autonomous Drone

Figure 16 Drone (Indiamart, 2018).

Background

Drones have emerged as a global trend in recent years, and has attracted interest ranging from hobbyists, professionals, industry applications and the military. Developments in cameras, batteries, sensors and increasing degrees of autonomy is expected in the future.(CASTELLANO, 2018).

Intel believes that advanced drones can capture damages even better than humans .(Runyon, 2017).

Problem

Due to high rotational speeds of the rotor blades, contact with different elements can lead to forms of erosion like pitting, gouging and delamination. Several studies have found that erosion on blades can decrease annual production of up to 20%. In offshore wind, the problem is especially critical, as repairs require costly downtime and challenging offshore operations.(Combest, 2016).

The blades are one of the most expensive component on the turbine, and the process of replacing or repairing the blades are even more expensive, requiring jack-up vessels as a major cost driver. (Carroll et al., 2016)

Existing solution(s)

1. Rope access technique: Possible to inspect 2-5 turbines per day. Poses risk to technician, and is costly due to vessel chartering and small amount of turbines inspected per day. Weather windows limits accessibility.(Deign, 2016).

2. Ground based camera: 2 hours per turbine, but need to access each turbine. Operated by humans and necessary to reposition blades to for inspection to be completed. Costly due to vessel chartering and small amount of turbines inspected per day. Weather windows limits accessibility.(AtSite, 2018)

3. Drones piloted by professional operators: Possible to inspect 10-12 turbines per day. Costly due to vessel chartering, but less dependent on weather and reduced risks for technicians.(Deign, 2016).

Description of idea

The idea is to use a drone that by itself can inspect the blades, but also other components if desirable. The drone will be located at a garage for protection in between the inspections. Charging and internet access will also be available at the garage. The inspection will be documented by cameras on the drone.

Function

1. Drone is located at the garage at the base of the turbine, connected to induction charging through its landing gear and to the internet for connection to the operation center.

2. According to the inspection program, a turbine is to be inspected. The drone will then start up and take-off as the garage port opens.
3. The drone flies towards the selected turbine based on GPS coordinates and optimal path algorithms
4. The blades will then be identify with object detection algorithms based on what is viewed through the cameras.
5. Lidar sensors ensures that an appropriate distance to the blades are kept, and blade condition is documented by the cameras on the drone.
6. Drone returns to station, where the information collected in the inspection is transferred to a cloud computing solution and made available to operators.

Product quality

This product is unique in solving the problems identified. An unique accessibility and consistency of inspection will be possible, while reducing the large costs involved in current solutions.

Problem size

The market for drone use in inspection of offshore windfarms is an established market

4.3.3 Additive Manufacturing

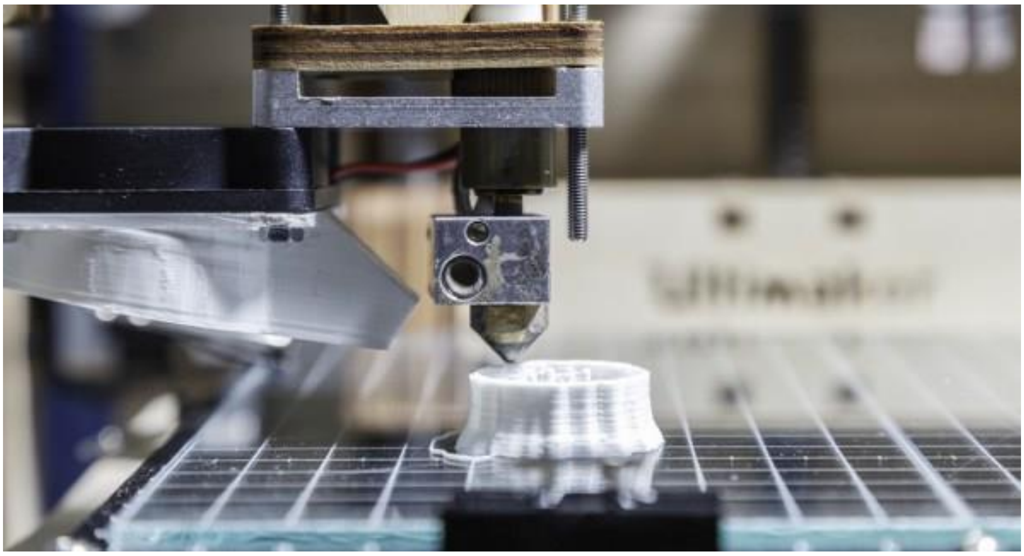


Figure 17 adding layer-on-layer in additive manufacturing (Worth, 2015)

Background

The spare part market have are mostly limited to OEMs, and according to (Hassan, 2013): “owners have expressed some dissatisfaction at the cost, quality and lead times required for even quite basic spare parts such as lubrication oil and are keen to see a spares market emerge”.

Problem

1. Warehousing of spare parts are costly.
2. Ordering spare parts involves lead time and transportation, often causing increased downtime of turbines.
3. Modern wind turbines are increasing in size, making transportation to port challenging.

(Dodd, 2017).

Existing solution(s)

Spare parts are produced by conventional manufacturing methods, and the most common solution today is to outsource spare part management to OEMs. Everything from warehousing to replacing components are usually outsourced to OEMs, with owners/operators only having an up-time requirement. (Kleinhoven, 2017)

Description of idea

The idea is to use additive manufacturing to produce spare parts. Locating additive manufacturing facilities at strategic ports or offshore platforms to reduce lead-time, warehousing needs, transportation time and cost, and turbine downtime.

Function

1. Condition monitoring system detects failure of component
2. Severity, location and criticality is specified and documented into spare part management system. Order is then sent to manufacturing facility.
3. Order is received at facility and spare part is manufactured.
4. Spare part is brought along to the turbine and installed by technician

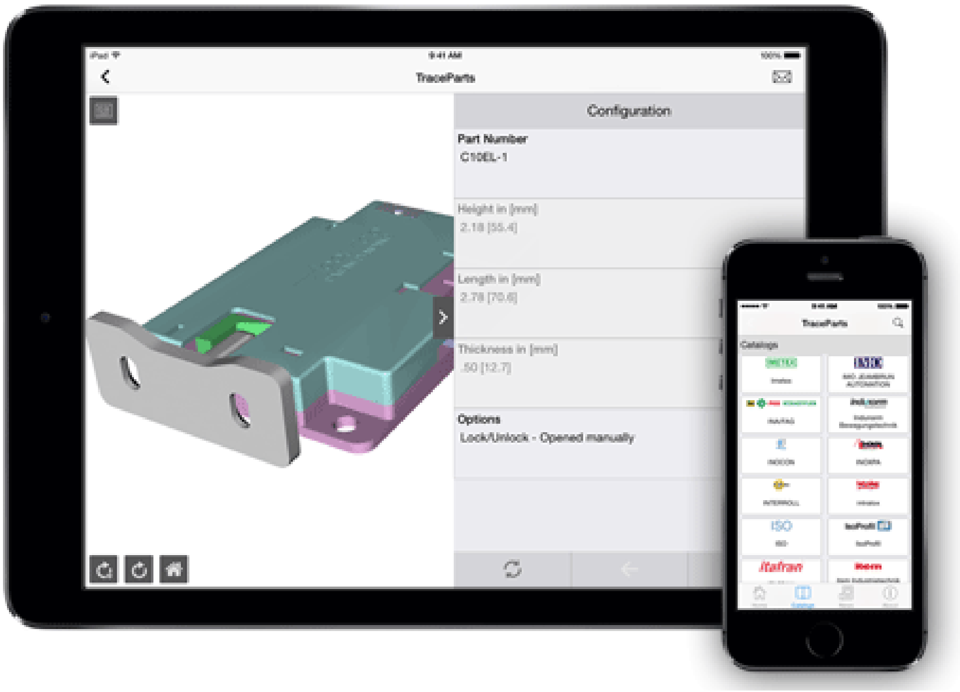
Product quality

Unique due to on-demand availability and location.

Problem size

This problem is big enough for companies to be willing to pay for it, and with some parts being too big for land based transport, they may have to pay for it in the future. GE and Vestas are companies that have already adopted additive manufacturing, mainly in prototyping, as technological maturity still has a long way to go (Dodd, 2017).

4.3.4 Digital maintenance application



Part Number
C10EL-1

Height in [mm]
2.18 [55.4]

Length in [mm]
2.78 [70.6]

Thickness in [mm]
.50 [12.7]

Options
Lock/Unlock - Opened manually

Figure 18 digital model of asse t(Traceparts, 2018).

Background

According to (Fitch-Roy, 2013), in an EWEA report, nearly 50.000 workers will be needed by the wind power industry in Europe by 2030, with O&M being the biggest source of demand of skilled workers. These predictions comes on top of a current lack of 7000 skilled personnel in the industry today.

Problem

(Donnelly, 2018) states that information and support is sometimes insufficient, and “even the most experienced technician requires access to additional resources/expertise while performing work. This information is difficult to obtain while up-tower and can lead to longer downtime”.

Existing solution(s)

By the practice that is common today, in many field inspections and maintenance activities, the findings are often not communicated back for analysis and sometimes not even reported at all. (Donnelly, 2018).

Description of idea

The idea is to develop an application with 3D models, turbine condition information, historical data of turbine, and augmented reality features for live support and guidance from remoted expertise. The application can be installed on a tablet, connected to smart glasses so that the supporting experts can see through the "eyes" of the technician in the turbine. The application gives the technician access to condition monitoring data and other relevant information that is available to the onshore operations center.

Function

1. Technician is transferred to turbine, and the maintenance software lists the task to be conducted and tools necessary to perform task.
2. The relevant component is highlighted in a 3D model of the turbine. Sensor data is also available real-time, to inform technician on the condition of the turbine systems and components.
3. Technician identifies component with the help of the 3D model, and verifies that failure mode and condition information from maintenance software is correct.
4. Suitable maintenance action is selected, and performed with live support available.

Product quality

10-20% better than existing solutions, because typical causes that will lead to downtime and work being incomplete can see a reduction with this solutions.

Problem size

Real problem, but has not been an area of focus in the industry.

4.3.5 Digital twin

Figure 19 digital twin of a windfarm. (Annunziata, 2015)

Background

Computer aided design (CAD) models have allowed virtual representations physical assets for more than 30 years, but developments in recent years have made digital twins at the forefront of disruptive technology. It is predicted that by 2021, half of large industrial companies will use the technology, and thereby gain an expected 10% improvement in effectiveness. (Pettey, 2017)

Problem

According to (DNVGL, 2018), asset operators face various challenges in in O&M management, among these are:

- Scheduling of inspections
- Predictability of failures
- Budget planning
- Resource planning (spare parts, crew, vessels, etc.)
- Knowing if turbine performs optimally

Existing solution(s)

Several solutions exists to these problems, typical for most solutions is that they are designed to solve one or a few of these problems. Examples are condition monitoring systems, enterprise resource planning software, SCADA, etc.

Description of idea

The purpose of the digital twin is to provide a digital representation of the whole windfarm, that accurately replicate the performance and dynamics of the windfarm. By applying adaptive analytics and machine learning algorithms on the stream of weather data, and data from sensors on the turbines, the digital twin will continuously improve its predictive and simulation capability.

Benchmarking of performance in different conditions, expected failure development of components, simulation of offshore activities are some of the benefits the digital twin provide operators.

Function

Production:

Tracking of production in when several conditions are met, and establishing benchmarks for productions in these conditions can help operators determine when turbines are producing optimally.

Failure prediction:

Alerts are given when a pattern that could lead to failure is detected by predictive analytics, specifying current condition and expected remaining lifetime.

Offshore O&M activities:

1. Maintenance actions and characteristics are selected by operators
2. Optimal path, vessel and crew requirements, budget and duration is calculated based on simulation in the digital twin.

Product quality

10-20% better than competitors, due to increased simulation capabilities compared to suppliers of similar digital twin solutions.

Problem size

Established market, there are already companies that provide digital twin solutions but the market are still very open, as the available solutions have only existed a few years.

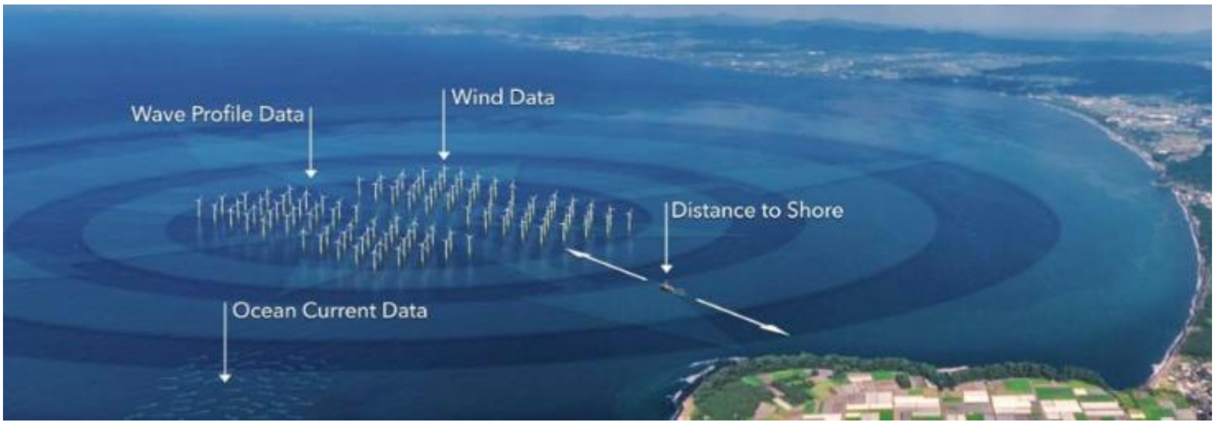


Figure 20 input data for digital twin. (Offshorewind, 2015).

4.3.6 Predictive maintenance

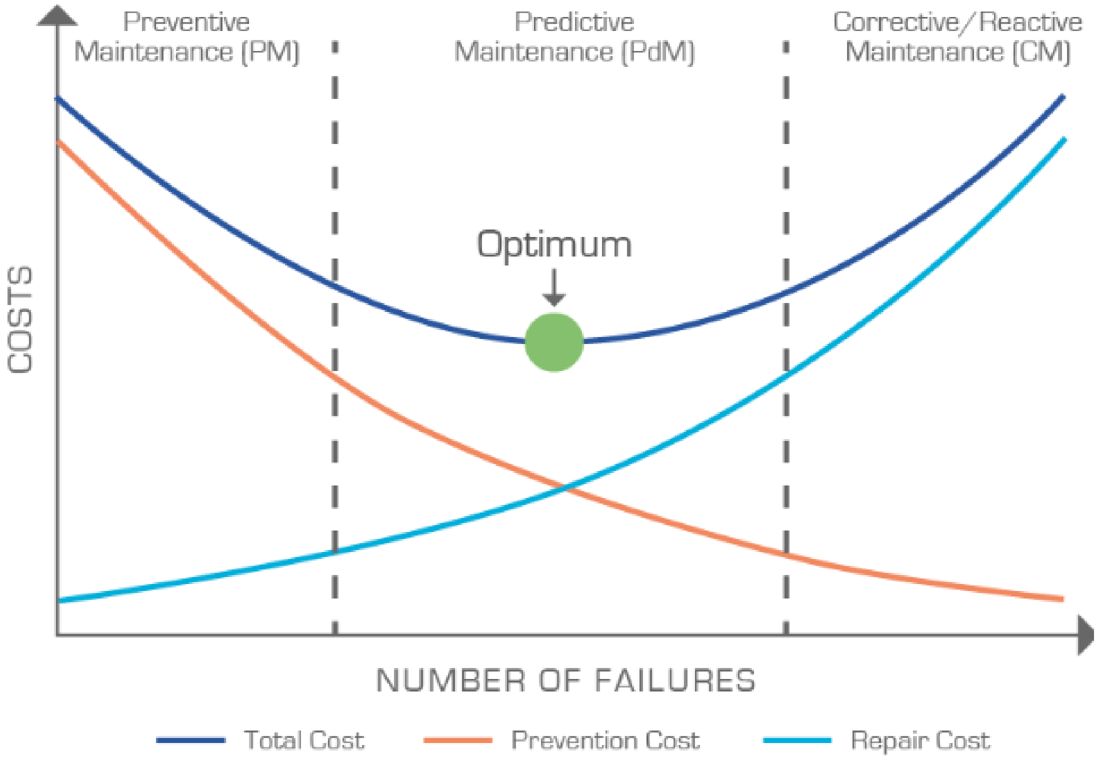


Figure 21 benefits achieveable by predictive maintenance (SANGER, 2017)

Background

Cost of sensors, and hardware for computing, data storage and processing have decreased significantly, while technological advances have increased connectivity, mobility and real-time information transfer.

Sensors capture real time changes in condition parameters in their operating environment. Predictive analytics have the ability to use this information to diagnose assets and give prognoses, giving asset owners and operators predictability in planning of maintenance and production. (OutSmart, 2018)

Problem

Critical components (gearbox, blades, bearings, shafts) are frequently not utilized through full technical lifetime or run for too long, leading to fault propagations, unwanted downtime, and costly interventions in challenging offshore environments with limited weather windows and high costs of vessel chartering. (Harman, 2012).

(Hassan, 2013) have identified two main challenges for a predictive maintenance strategy in offshore wind:

1. "Improving plant condition monitoring equipment and algorithms to interpret early onset of component failures
2. Increasing offshore wind data set"

Existing solution(s)

It is observed that most wind farms still conduct maintenance in a traditional manner; pre-determined, calendar-based maintenance regardless of condition and performance or corrective maintenance after unexpected failures have occurred. (OutSmart, 2018).

Description of idea

Using predictive analytics do prognostics on wind turbine components. The prognostics will give operators an expected remaining lifetime, which will make it possible to plan preventive actions, or order spare parts to when the component fails.

Function

1. Collect data: Data is collected by sensors, and sent to the cloud. Vibration data is collected from accelerometers, and so on.

2. Analysis of data: Data from operating equipment is analyzed and the software will classify whether the equipment is operating normally or not. This process requires large datasets for the analysis to be accurate.

3. Prediction: From large datasets collected of normal operations and failures, machine learning techniques is used to predict when a failure will happen. Convolutional neural network are an example of a suitable use of machine learning for this purpose. This form of deep learning, neural network will

identify the characteristics of normal operation, the changing values in data that leads to failure and by this, predict time to failure.

4. Report: Status on equipment is then reported. Prediction of failures are presented with remaining lifetime and percentage intervals for likelihood of the prediction to occur.

(Foxworth, 2017)

Product quality

At least 50% better. A return on investment of more than five times the investment have been reported by a company adopting predictive maintenance. (Romaxtech, 2016).

Problem size

Established market. The market ranks as established but not very developed. This is because it has mainly been dominated by OEMs, but are now starting to open up. (Hassan, 2013).

4.3.7 Proactive yaw and pitch control

Figure 22 pitch control by rotating blades (Barnard, 2018)

Background

Studies have shown that even simple control strategies in collective pitch control assisted by LIDAR sensors can significantly reduce fatigue and extreme loads. Small load reductions were also achieved in an test application of individual pitch control, with a potential for further improvement with more advanced strategies. (Bossanyi et al., 2014).

Both simulations and real test application of LIDAR based collective pitch control verified benefits of rotor speed regulation and tower base load reduction.(Clifton et al., 2018).

Cost of LIDAR sensors have decreased dramatically in recent years.(Muoio, 2017).

Problem

Extreme wind conditions and sudden, strong wind gusts can significantly decrease lifetime of drivetrain components. (Dvorak, 2015).

Existing solution(s)

The most common solution today is to have a yaw system that orients the rotor towards the wind direction after sensors on the wind turbine have measured the wind that has already passed. Control of the pitch is also managed by using the information from the same sensors, in a reactive way. (Lund, 2018).

Description of idea

The idea is to install LIDAR-sensors on the turbine and use the measured wind speed, direction and shear to proactively control the yaw and pitch. By being proactive instead of reactive, the wind turbine can better control loads subjected on the turbine and the power produced.

Function

The picture below illustrates the functionality of an control system based on LIDAR sensor data. The data from the sensor is fed into a wind field model to determine most effective pitch and yaw configurations in relation to the wind conditions. The adaptive filter is used to filter out uncorrelated data, to avoid unwanted actions of the control system.

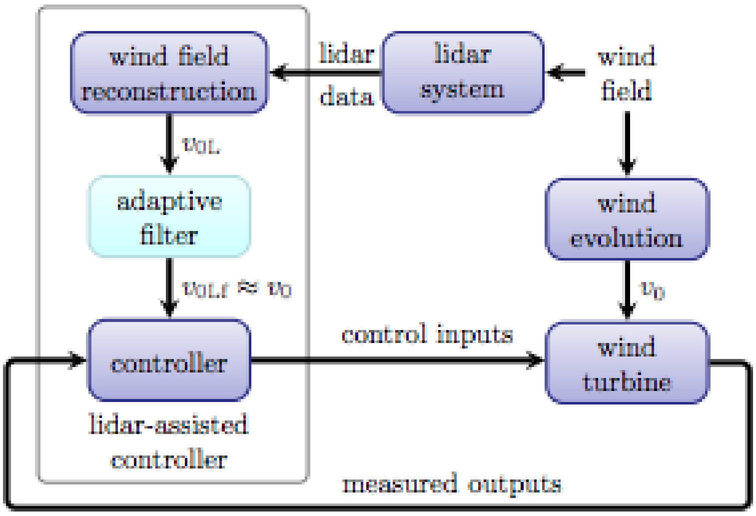


Figure 23 Control loop of a LIDAR-based system. (Clifton et al., 2018).

Product quality

This is an unique solution to the problem compared to existing solutions.

Problem size

This problem is in the range between a recognized problem and a problem someone is willing to pay for. This is because the problem is recognized and a few applications are seen, but a widespread adoption have not yet emerged.(Clifton et al., 2018).

4.3.8 Blockchain-based contract and agreement system

Figure 24 blockchain, facilitating digital agreements (Metacaresolutions, 2018).

Background

Blockchain technology has emerged in recent years, promising secure peer-to-peer transaction and information sharing, making business processes potentially much more efficient and less time consuming.(Hooper, 2018).

Problem

Paper work, documentation and agreements involve brokers, lawyers, banks and other third parties. This is both time consuming and costly, and can lead to conflicts and misunderstandings. (Hooper, 2018).

Existing solution(s)

Different ERP and computerized maintenance management systems (CMMS) software are used to solve some of the identified problems (Donnelly, 2018).

Description of idea

A system where contracts and other agreements are stored, and documentation of inspections, services and other O&M activities are accounted for. This will give owners/operators and service providers a common platform with traceability and transparency, with full overview on what has been done, by whom and when, and avoid misunderstandings and conflicts.

Function

1. Operators and service providers reach an agreement.
2. Terms and conditions is uploaded the ledger.
3. Both parties verify and sign digitally.
4. When a service is provided, this is documented and verified by the involved parties and stored in the ledger

Product quality

20-40% better than existing solutions

Problem size

Recognized problem

4.3.9 ROV inspection

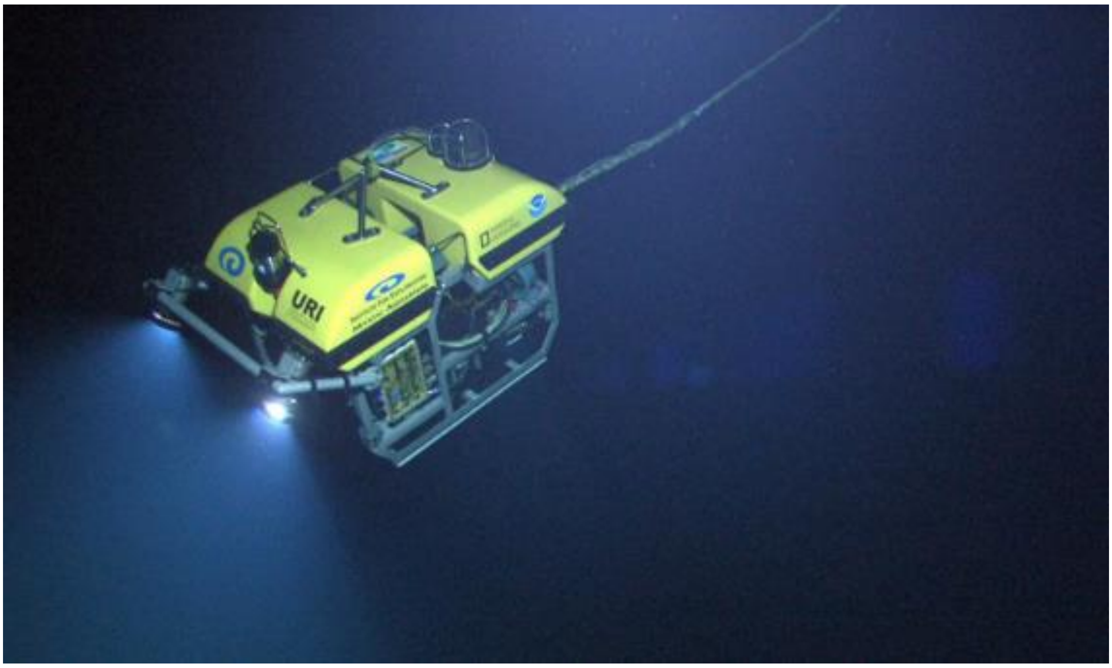


Figure 25 an underwater ROV(Pirpir5, 2014)

Background

German authority demands permanent monitoring of structural integrity of 10% of foundations in windfarms (Mathiesen et al., 2016).

Problem

Almost 40% of offshore wind turbine monopile foundations have potential grouted joint issues (Tomlinson, 2018).

Corrosion is big problem in wind turbine foundations (Mathiesen et al., 2016).

Substructure problems include scour, marine growth, deformation, corrosion and sediment displacement

Existing solution(s)

Divers and/or ROV controlled from vessel are two most common solutions for inspection of the abovementioned problems. (Knight, 2014).

Description of idea

A ROV stored at the turbine, connected to fiber optic cables for remote, on-demand inspection of the substructure.

Function

The ROV is connected to controllers and internet access through cables at the turbine foundation, and controlled from onshore operations center on-demand.

Product quality

10-20% better than existing solutions, due to availability on-demand.

Problem size

Established market

4.3.10 Mobile robot blade inspection

Figure 26 mobile robot inspection(Invisotech, 2018)

Background

Remote operations are identified as a key contribution for the offshore wind industry to reduce cost of energy and be competitive in the future. (Madigan, 2018).

Problem

- Damages to tower and to wind turbine blades are the most frequent damage on the structural part of wind turbines.
- Blades account for about 15-20% of the total cost of a wind turbine, and damages on blades constitute of the largest repair costs and longest time to repair.
- Fatigue, delamination and adhesive joint failures are common damages to turbine blades.

(Shohag et al., 2017)

Existing solution(s):

1. Rope access technique: Possible to inspect 2-5 turbines per day. Poses risk to technician, and is costly due to vessel chartering and small amount of turbines inspected per day. Weather windows limits accessibility.(Deign, 2016).

2. Ground based camera: 2 hours per turbine, but need to access each turbine. Operated by humans and necessary to reposition blades to for inspection to be completed. Costly due to vessel chartering and small amount of turbines inspected per day. Weather windows limits accessibility.(AtSite, 2018)
3. Drones piloted by professional operators: Possible to inspect 10-12 turbines per day. Costly due to vessel chartering, but less dependent on weather and reduced risks for technicians.(Deign, 2016).

Description of idea

A mobile robot wheels, connected to tower and blades by magnets. To inspect surface damages, thickness deviations and cracks, the robot is equipped with sensors for vision, ultrasonic testing, distance and size measuring.

Function

1. Robot is started from onshore operations center
2. Robot conducts inspection and document damages and location.

Product quality

10-20% better, due to remote capabilities but limited mobility compared to drone.

Problem size

Established market.

4.3.11 Remotely controlled inspection

Figure 27 Remotely controlled operations (Immersive-Technologies, 2018)

Background

Connectivity has enabled remote presence and mobility. Combined with the reduction in prices of sensors and computer-related hardware, remotely controlled products have the ability to replace physical presence of operators.

(Netland et al., 2014) showed that a robot with sensors resembling human senses could replace humans without significant sacrifices in quality of some activities. The robot solution was applied to wind turbine context in simulations, which resulted in improvements in terms of cost of energy and availability, even with very conservative assumptions.

Problem

Inspections of offshore wind turbines are conducted based on warranty obligations, maintenance strategy and as part of pre-inspections after failures have occurred or in the case of false alarms from condition monitoring system. Doing this is expensive, due to the direct costs of vessel chartering and technicians, but also by downtime caused by limited weather windows and time of transferring crew offshore.(Hassan, 2013)

Existing solution(s)

Technicians are transferred by vessels to the turbine, to investigate, observe and test components inside the nacelle and the tower.

Description of idea

A remotely operated robot, equipped with sensor to replace human senses, inspecting different areas of the nacelle and tower of the turbine. Cameras, microphones, and sensors to measure temperature and vibration are to be installed on the robot, in addition to hardware for processing and uploading of information to the cloud. Mobility is enabled by a rail solution, for reliable transport around inspection areas.

Function

1. Condition Monitoring system alerts operators with an failure, damage, or critical level of some parameter
2. A maintenance task is decided, inspection to reveal false alarm or in case of a failure, conduct pre-inspection.
3. The robot is steered to relevant location, to provide operators with vision, sound and other desirable information from the robot sensors.
4. False alarms are revealed, or real ones are evaluated for further action to take place.

Product quality

50% better, have shown same quality as humans in pilot of similar solutions. The product have additional features and can provide cheaper, unbiased information on-demand.

Problem size

Recognized problem/problem someone is willing to pay for. Research initiatives are looking at several similar solutions.

4.3.12 Intelligent Yaw and Pitch control for optimized wind farm O&M

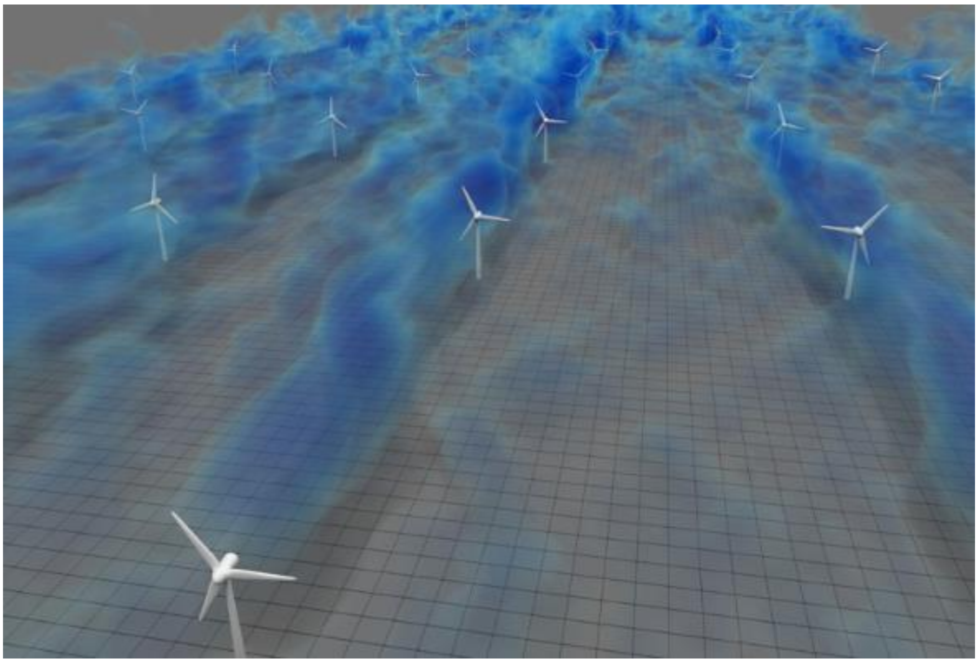


Figure 28 wake effects in a wind farm (AIP, 2014)

Background

Simulations have shown that a holistic pitch angle and yaw rotation with optimization of the whole wind farm in mind, have a potential for increasing electricity production by 0.5-3.5%, and also reduce load on some components with as much as 50%. (Carbon-Trust, 2017)

Problem

Wind exiting a turbine contains less kinetic energy than the wind that enters the turbine. This is because of the wake effect, which is the slowing down and turbulence that is created by wind that passes a turbine. The wake effect of turbines can influence the production and loads on the other turbines in the wind farm, dependent on distance to each other, terrain and the wind conditions. (Diamond and Crivella, 2011)

A turbine in the wake of another will produce less, and experience increased fatigue loads. (Kanev et al.).

Existing solution(s)

The current techniques are designed to maximize the production for each individual turbine. (Kanev et al.).

Description of idea

The idea is to actively control yaw and pitch with increased power production and reduced loads for the combined wind farm in mind. This is to be achieved by information about wind condition sampled by anemometers and/or Lidar sensors and processed by an optimization algorithm applied on a wind field model of the wind farm.

Function

1. Wind condition data is collected from sensors.
2. Optimization algorithm process data to optimized pitch and to reduce wake effects, considering the combined production and loads on turbines.
3. Yaw rotation and pitching are continuously adjusted for optimal advantages.

Product quality

Unique.

Problem size

Problem recognized problem. Large research project started in 2018, backed by key players in Offshore wind(Carbon-Trust, 2017).

4.3.13 Summary of initial screening

The initial screening is summarized in the chart below, where the innovation opportunities marked in blue are selected for further evaluation based on the initial screening, emphasizing product quality and problem size. Electricity storage, autonomous drone, additive manufacturing, predictive maintenance, using Lidar sensor for yaw and pitch control and remote inspection inside turbine are the selected to be further evaluated.

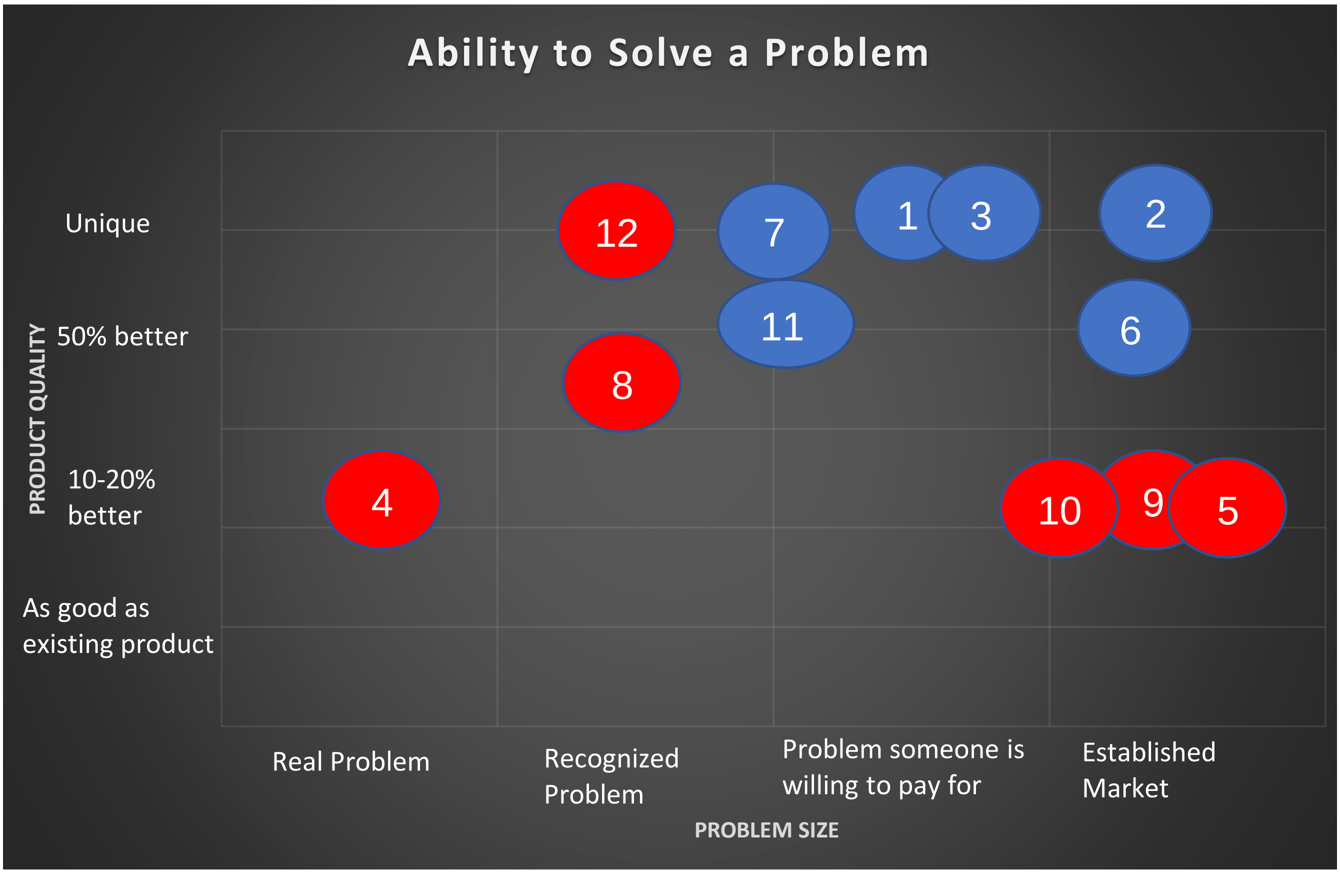


Figure 29 ranking of innovation opportunities based on problem size and product quality.

4.4 Opportunity screening

The innovation opportunities with the best scores from the initial screening was selected for further evaluation in this part. The purpose of this screening was to evaluate the opportunity of the product/service, in terms of market and profit size. Implementability and measures to protect intellectual property rights will also be evaluated, in addition to an assessment of the technology the product/service is based on.

Table 3 explanation of screening criteria for the opportunity screening.

Screening criteria	Description of criteria
Implementability	The requirements for implementation of the product/service. The evaluation includes an assessment of installation and system integration
Technology	A description of the technology behind the product/service.
Challenges	The main challenges facing the product/service?
Intellectual Property Rights	Measures to protect the product/service, to realize its potential and secure profit over time.
Profit Margin	The profit margin is evaluated based on the potential sizes of sales and margins. Ranging from lower than willing price to high margin, defined as a profit of 50%+.
Market	The size of the potential market, ranging from local to global.

4.4.1 Electricity storage

Implementability

Installation: Batteries can be installed both on land and offshore, land-based being significantly cheaper (Nilsen, 2016).Distance from land, available infrastructure and so on are considerations affecting choice of battery location. Either way, the batteries needs to be integrated in the wind farms transmitting solution, and including control features for regulation of storage and supply to grid.

System integration: the battery solution needs to be integrated into the electricity control system, taking into account variables like battery capacity, grid capacity, transmitting efficiency, grid demand, power prices and so on.

Technology

Current battery technology is already capable of serving the purpose described here. Even small storage can provide benefits in terms of grid stability and reduce daily fluctuations in electricity prices. (GE, 2018b).

Challenges

- Choice of optimal battery solution; In today’s battery technology, one has to choose between fast charging capabilities or large storage capabilities.(Nilsen, 2016)
- Integration into infrastructure
- Optimized market interaction
- Battery technology is advancing in a fast pace, timing of purchase to get the best value for the money will be challenging

Intellectual Property Rights

This innovation opportunity will be hard to protect, as various methods for using batteries in offshore wind has already been described and some have already been put to use. (DEIGN, 2018b).

Profit Margin

Good margins, perhaps in the range of 20-50% should be possible for this kind of solution, but due to difficulty of protection and potential though market situation, the profit margin will likely shrink after some years.

Market

Because the innovation opportunity will likely be easy to copy, it is likely that it would be limited to a national/local market.

Summary

The opportunity screening of this innovation opportunity is summarized in the chart below, highlighting the potential good margin in the first years and the transition towards lower profits in a growing competitive market. The difficulty of protecting acts as a barrier towards a bigger market, and limit the opportunity to a national/local market.

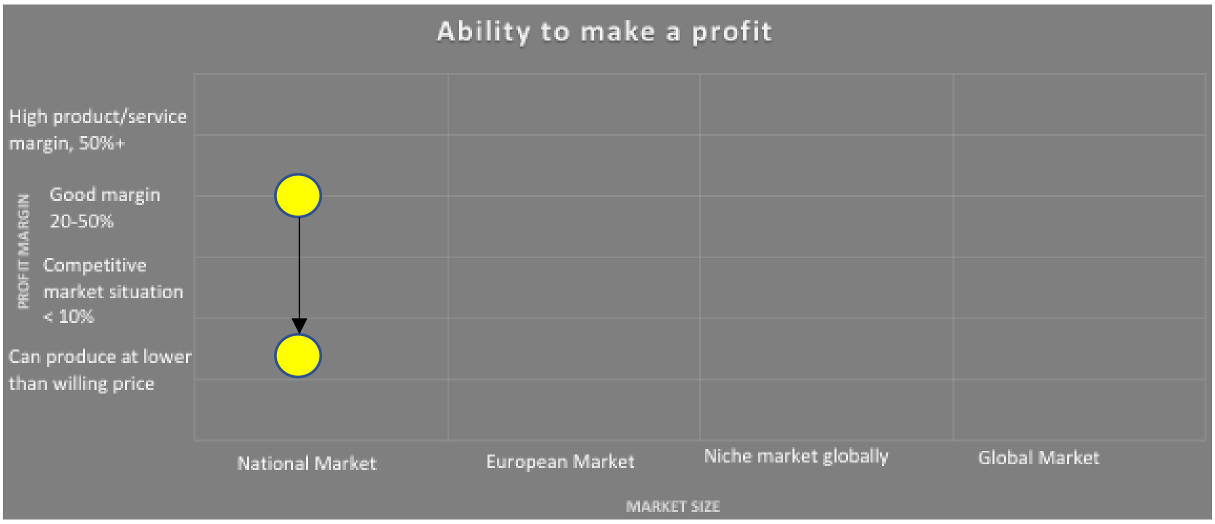


Figure 30 Electricity storage ability to make a profit

4.4.2 Autonomous Drone

Implementability

Installation: Installation of a garage, and a roof with open and close mechanisms. Also, the garage will have a floor allowing induction-based charging of the drone. The garage has to be installed at a turbine or O&M platform, with power supply and fiber optic cables.

System integration: a control and communication system must be created to obtain the data recorded by, and monitoring of the drone.

Technology

The drone needs advanced technology to perform the inspections, takeoff and landing autonomously. For the inspection program, the drone first get the GPS coordinates of the turbine to be inspected, and then make use of computer vision to identify blades, tower, their positions and defects. Input to this system is form sensors like LIDAR, sonar and infra-red, which helps in determining distances and avoid crashes. Visual and thermal cameras are used to capture and document defects and stresses in the inspected areas. (Brown, 2018).

Gimbal mechanisms are responsible for stabilizing against vibrations and turbulence, to allow capturing of clear pictures and videos. Emergency and control systems ensure that battery level is sufficient, enough motor power is available and so on. Return Home feature is used after inspections have taken place, and the drone will then recharge and upload inspection data to a cloud-based system for operators to assess blade and tower condition. (Brown, 2018).

Challenges

- National regulations for autonomous vehicles operating in airspace, in some countries its required that a human with overriding control is in the line of sight of the drone. (Runyon, 2017).
- Lack of standards for inspections is a problem stated by many experts, making use of autonomous inspection challenging.(Runyon, 2017).
- Reliability and robustness over time
- Data transfer and processing.

Intellectual property rights

The innovation opportunity can be protected by key partnerships with drone, garage and charging supplier, a company-developed inspection program and close follow-up on customer needs.

Profit margin

Compared to existing solutions, this autonomous drone could result in large savings for owners by reducing vessels and personnel offshore and remove the risk exposure in rope access inspections.

In a business model where the drone and the related equipment is leased to owners and the right measures for protection are taken, it should be possible to get high profits over time.

Market

The industry have already embraced drone use in inspection, so there should be a demand for the innovation opportunity described here, given its increased benefits compared to existing solutions. If a company succeeds in forming strong partnerships and protect their inspection program, the innovation opportunity can be suited for a global market. Other industries should also be interested in this kind of solution.

Summary

With strong partnerships, protection of the company's´ secret inspection program and a good business model, the innovation opportunity has the ability to make high profits over time in a global market.

Figure 31 autonomous drone ability to make a profit.

4.4.3 Additive Manufacturing

Implementability

Installation: Manufacturing facilities with strategic location have to be set up, as well as transportation lines and capacity.

System integration: Additive manufacturing has to be integrated into spare part management system.

Technology

The technology is currently best suited for prototyping, and production of more complex parts than typical spare parts. The cost of producing simple spare parts with additive manufacturing will not make it profitable for companies today.

It is better suited for development and production single parts that can replace multiple components produced with conventional manufacturing technologies. For example, a 3D printed mold for turbine blades reduced the production time by 35% and allowed for new possibilities like air ducts that was not possible with other manufacturing methods and was one of the reasons for the increased production speed. (Dodd, 2017).

Challenges

- Technological maturity.
- Cooperation with OEMs with respect to tolerances, material and other warranty related issues.
- Creation of new business models: leasing of manufacturing facilities, access to spare part file library etc.

Intellectual Property Rights

Components designed for and produced by additive manufacturing can be sought to be protected by patents, and the product can be delivered as a ready-to-print files from developers to additive manufacturing shops.

Profit Margin

With the technology currently available, producing spare parts similar to those produced by conventional manufacturing, additive manufacturing will not be profitable. However, for more complex parts and supporting products, like molds, additive manufacturing can be very profitable.

Market

For simple spare parts, the challenges and technology will not be profitable and therefore not competitive in any market. More complex parts and supporting products can be profitable in a global market.

Summary

The technology and costs in additive manufacturing are not in favor of building a new business in offshore wind. Rather, it's more suitable for the large manufacturers for support of conventional manufacturing and development of new components, which is where its currently used today. This fact is illustrated in the chart below, where the use of additive manufacturing in simple spare parts are related to low profits in national markets, while new, complex parts have high profit potential in global markets.

Figure 32 Additive manufacturing ability to make a profit

4.4.4 Predictive Maintenance

Implementability

Installation: Modern wind turbines usually have a SCADA and Condition Monitoring systems installed, which produce large amounts of data (DNVGL, 2018). The proposed idea can add significant value from data that is collected from already installed sensors and systems. Dependent on the scope for predictive maintenance, extra sensors can also be installed.

System integration: Communication lines has to be created to give predictive maintenance service providers access to turbine data. Also, channels between operators and service providers has to be created, for communication of reports.

Technology

Various technologies exists for predicative maintenance. On rotating equipment, vibration analysis have proven to give good indication of machine health and prognosis. Vibration data is collected by the use of accelerometer sensors, and the data can be analyses by trend analysis to determine state of equipment and give prognosis. This can be applied to rotor bearing, gearbox and generator bearing.(Fischer and Coronado, 2015).

Oil analysis can be used for predictive maintenance on gearbox. Particle concentration, wear debris, viscosity and temperature are properties that can be monitored by commercially available sensors.(Fischer and Coronado, 2015).

Also, sensors measuring acoustic emission sensors can be applied to detect generation and propagation of cracks. This method has proven successful for gearboxes, bearings and blades in wind turbines. (Fischer and Coronado, 2015).

The listed methods have already proven successful. After enough experience with the listed methods have been gained, and enough data has been collected, more advanced analytic methods, like deep neural networks can be used to further develop predictive maintenance methods.

Intellectual Property Rights

Some proven diagnostic techniques exist today, but the application in offshore wind have been minor. A major problem in offshore wind is the lack of data, caused by protective manufacturers but also by the fact that very few turbines have been operating a full lifetime yet, reflecting an industry that have a long way to maturity.(Dinwoodie, 2017).

The key to this innovation opportunity is apply proven predictive maintenance methods, develop promising methods, and experience. Because of the lack of similar solutions and experience in offshore wind, the experience developed have to be protected as a company secret, and used to ensure competitive advantage.

Challenges

Several challenges exists for predictive maintenance in offshore wind, especially the lack of data, mainly caused by protectionism by manufacturers. Other challenges have been identified by (Fischer and Coronado, 2015) and are the following:

- Sensor reliability and accuracy
- False alarms and missed faults
- Severity assessment

Profit Margin

Due to the lack of experience in the industry, it should be possible to make good profits over time by focusing on developing strong competence, and ensure that key personnel stay committed to the company.

Market

The innovation opportunity have a potential to reach a global market. Both offshore and onshore operators can be potential customers. The knowledge gained from wind power in predictive analytics may well be transferrable to other industries, in what is thought of as becoming a global trend and a significant value addition in the future.

Summary

Summary of the opportunity screening of predictive maintenance is illustrated in the chart below. The innovation opportunity is thought to be able to generate a good profit margin in a global market. However, strong competence and protecting of the company methods are important, and can prove to be difficult. With most modern turbines having lots of installed sensors already, this innovation opportunity should be relatively easy to implement.

Figure 33 predictive maintenance ability to make a profit.

4.4.5 Remotely controlled inspection inside turbine

Implementability

Installation: Installation of a rail to in all desirable areas that the robot needs to cover. As part of the rails, there will be a conductor, supplying the robot with electricity. At the starting point of the rail, the power connecting cables are connected and also fiber optic cables for internet access. A Wi-Fi router also needs to be installed, allowing operators remote control of the robot and access to real-time data from its sensors.

System integration: A system for control, data transfer and storage have to be developed.

Technology

Equipped with visual and thermal camera, microphone, thermometer, accelerometer and such, the robot will provide operators with a continuous stream of real-time data from inside the turbine. For fast and easy access to inspection areas, a program that locates the desired areas with reference to distance from rail starting point will allow operators to easily steer the robots to the gearbox, bearings, shaft, etc. The robot will have a central processing unit, electrical motor, battery and hardware for storage of data.

Challenges

- Sensor reliability and accuracy
- Lack of industry standards

Intellectual Property Rights

A robot equipped with varied and useful sensor capability could experience some protection in form of key partnerships and try to patent their methods. Patenting may prove hard, and also useless, as the product capabilities should be relatively simple to copy.

Profit Margin

Profit margins may be good in the first years, but difficulty of protection will put pressure on profits in global markets.

Market

A national market might prove to be the limit for this product, but if a good and cost-efficient product is developed, a niche market globally could be possible, as the product addresses problems that are not top priority for owners.

Summary

A reasonable amount of work should be expected installing the product inside the nacelle, and setting up the control system. The shrinkage of profits in a global niche marked is illustrated in the chart below.

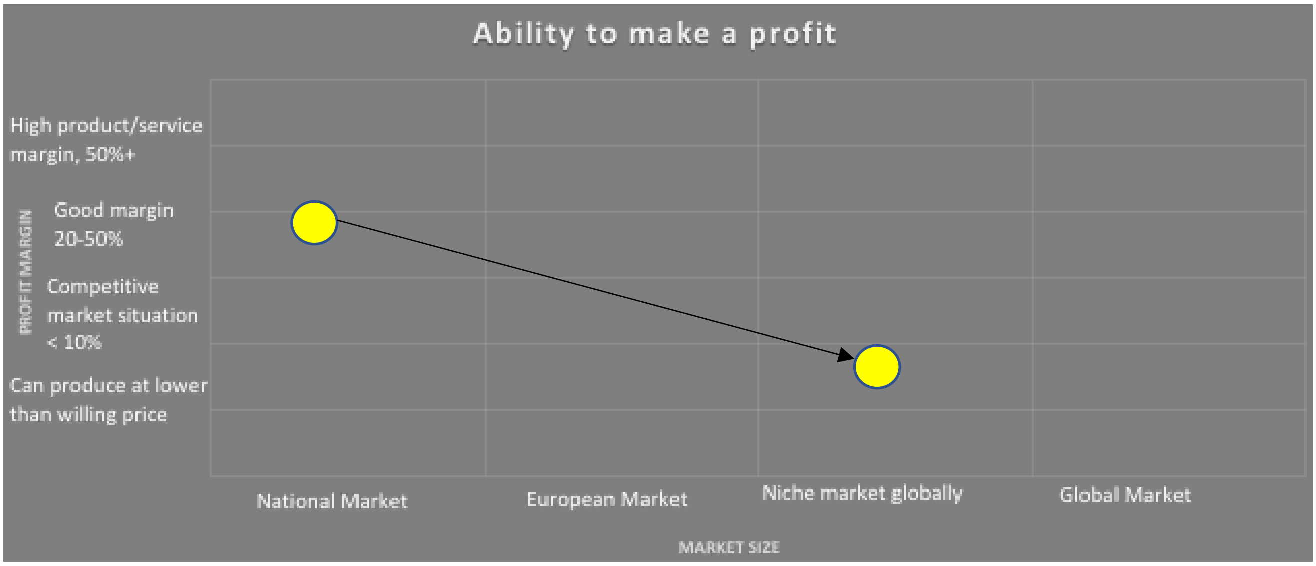


Figure 34 remotely controlled inspection inside turbine ability to make a profit

4.4.6 Proactive yaw and pitch control

Implementability

Installation: The installation of a turbine mounted LIDAR sensor has proven to be a relatively easy task, and can be completed in a single operation.(Wagner and Davoust, 2013).

System integration: Integrating the Lidar sensor into the yaw and pitch control system requires development of a wind field model that translate the data from the Lidar sensors into yaw and pitch adjustments.

Technology

Lidar technology transmit pulsating laser, and distance is calculated based on when an object is hit, and when the pulse is reflected back. Speed, distance and chemical properties can be determined by the use of Lidar sensor. (Coldewey, 2017).

Challenges

- Sensor reliability and accuracy
- Wind field model configuration

Intellectual Property Rights

The wind field construction that uses data from the LIDAR sensors to configure yaw and pitch position could either be patented or kept as a company secret. A patented solution could be the basis of a business model based on subscriptions, but also make it easier for the competition to adopt similar control strategies. Keeping it a company secret would mean that the most suitable business opportunity would be delivering a complete solution with sensors and installation to customers.

Profit Margin

The product will give good benefits to customers, and will not be expensive to reproduce, therefore good profits can be achieved.

Market

Even though some protection can be achieved, similar products can be produced by competitors relatively easily. A national market may therefore be the most likely for this product.

Summary

The product may earn good profits in the first years in national markets, but international markets may prove harder, as the solution can be copied relatively easy. However, the costs to reproduce can be very low, opening up an opportunity for a global niche market with slightly lower margins.

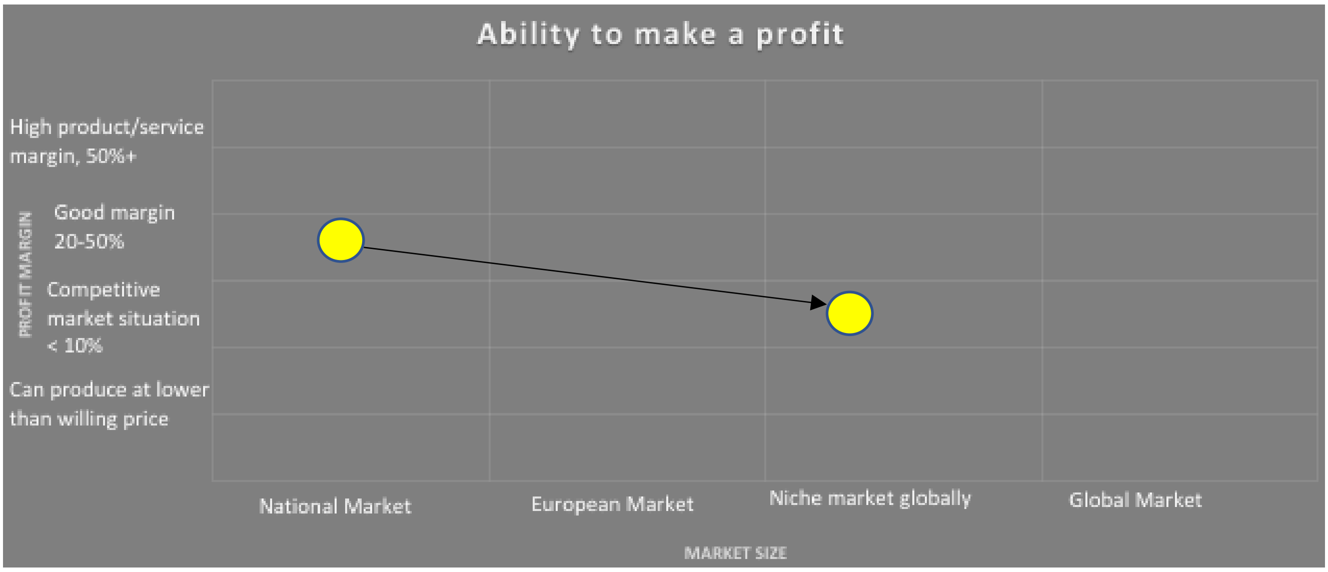


Figure 35 Proactive yaw and pitch control ability to make a profit.

4.4.7 Summary of Opportunity screening

Additive manufacturing and electricity storage are both likely to play a part in offshore wind in the future, but both are at very early stages in terms of technological development and usefulness in the industry. Also, owners are working directly with battery companies, and the large manufacturing companies are developing their own additive manufacturing technologies, which makes it hard for new businesses to enter the market.

Remotely controlled inspection inside turbine is a relatively simple product, but could require a lot of work to install and set up, which can prove to be a barrier as the product is not addressing owners´ main concerns. A yaw and pitch control system using Lidar sensors are very promising, and should be adopted in a wide scale in coming years. However, it may be easy to copy, and low profits may be likely for larger markets.

Based on the evaluation in the opportunity screening, the autonomous drone and predictive maintenance was selected to be presented in a business model canvas. The two were selected instead of the others, because they should be relatively easy to implement, the technologies involved are available today, measures can be taken to protect them from competition and therefore they were seen as suitable for building a business.

4.5 Business model canvas

The most promising opportunities from the two previous screenings, based on the evaluation criteria, will in this part be presented in a business model canvas. The canvas is used to illustrate how the business model of the opportunity can be set up to deliver value. The business model canvas used here is based on the 9 building blocks presented in (Martin, 2015):

1. Customer segments
2. Value propositions
3. Channels

4. Customer relationships
5. Revenue streams
6. Key resources
7. Key activities
8. Key partnerships
9. Cost structure

4.5.1 Autonomous drone

1. Customer segments

There are mainly two potential customer segments:

- Customers wanting to outsource inspection.
- Customers wanting a hands-on approach.

To fit customer needs, the company can offer different solutions. The solution most appropriate for the first segment would be do the entire job, and report condition on inspected blades and tower to owners.

The second segment, where owners would seek to have a more hands-on approach, the inspection program can be programmed to the owners requirements and communication and data transfers lines can be set up directly to the owners. The companies would have a maintenance agreement.

2. Value propositions

The solution delivers value to each customer segment in many ways. First off all, it gives the customer an unique accessibility, inspections can be carried out on-demand, by the click on a button.

Second, the inspection program ensures consistency by inspecting the same areas in each inspection and documenting it.

Risks are also reduced by avoiding people and vessels offshore, as well as a significant cost reduction from reducing offshore trips.

Both customer segments will get a solutions that should be very easy for them to use, and the segment that goes for a complete solution included analysis of inspection results, will enjoy the benefits of a high-quality analysis performed by a team that after a while could have experience from hundreds of turbines.

3. Channels

The main channels will be direct contact and meetings with potential customers, in combination with website for information on benefits and contact information. Presence on conferences and industry meetings should also be prioritized.

After the first contracts, the company will extend its reach to potential customers, advertising results and customer success stories on industry websites.

4. Customer relationships

Customer relationships will maintained through dedicated personnel for both customer segments. For one of the customer groups, there will be a direct contact with the company´s analysis group.

5. Revenue streams

For both customer segments, the company shall receive payments on time-based intervals, from a subscription agreement, varying in size dependent on customer needs. The hands-on customer will receive and pay for inspection data on-demand, with a fixed minimum inspection rounds. The other customer segment will receive reports on asset condition with a specific frequency, which will depend on agreement.

6. Key resources

Human resources:

- Technicians for maintenance of drone, garage and charging equipment (personnel from key partner).
- Material specialists for analysis of inspection data
- Software engineers for programming of drone
- IT engineers for communications and data transfer functions from drone.

Physical resources:

- Drone, garage and charging equipment (delivered by key partners)

Intellectual resources:

- Partnerships with drone, garage and charging equipment suppliers
- Analysis methods.

7. Key activities

- Programming of drone
- Maintenance of drone, garage and charging solution
- Analysis of inspection data

8. Key partnerships

- Drone Manufacturer
- Garage manufacturer
- Charging equipment supplier

9. Cost structure

The direct costs for the company will be cost of equipment and salaries to employees, for programming, maintenance and support of the equipment, and analysis of inspection data.

4.5.2 Predictive maintenance

1. Customer segments

The predictive maintenance services can be tailor-made to customer needs, typically a customer may want only predictive services on critical components, or they would want on the whole turbine, both mechanical and structural components.

2. Value propositions

Predictive maintenance drastically reduce costs for customers, by increasing predictability of failures, so that the customer can plan when to either do preventive maintenance, repair or replace actions. This increased predictability can reduce vessel costs, reduce costs and frequency of time-based maintenance and help optimized amount of work done in each trip offshore.

For customers, the ability to predict future costs and production will increase by the use of predictive maintenance, in addition to optimize spare part management.

Putting it all together, an increase in availability, capacity factor and reliability should be experienced by customers.

3. Channels

The key channels for meeting customers will be presence at offshore wind conferences, directly contacting and meeting potential customers and the company´s own website.

Services and support will be delivered using common ICT tools, like cloud computing solutions and Skype.

4. Customer relationships

Direct communication with customer, because this will be a continuous service with regular reports on asset condition and diagnostics.

5. Revenue streams

Cash flow will be secured by continuous payments at set interval for predictive maintenance services. Sales and installation of additional sensors can extend size of the agreements.

6. Key resources

Human resources:

- Analyst and diagnostic expertize
- Expertize on materials, mechanical and structural components
- Software engineers
- ICT specialists

Physical resources:

- Sensors

- Computational capacity

7. Key activities

- Diagnostics of mechanical and static structures and components.

8. Key partnerships

- Sensor suppliers
- Cloud computing suppliers

9. Cost structure

The main costs will consist of payment to employees, computers with additional equipment and office space.

5 Discussion

The systematic approach was successful in identifying and evaluation innovation opportunities emerging from technology trends, that could be suitable to build a business around. The way the method was used, favoured exploration of the potential of a new product or service, that is going to be enter the market. As such, it may be very useful for entrepreneurs seeking to explore the business potential of innovation opportunities.

On the other hand, the results of the evaluation process in this thesis do not necessarily reflect what would be the best investment cases for wind farm owners. The digital twin and electricity storage, for example, were not favoured in the evaluation process, but for owners of a wind farm, they may very well be invaluable to stay competitive in the future of offshore wind. However, the criteria in the screenings can be applied in other ways, and be of great value to both asset owners and entrepreneurs.

The research and analysis of the technology of the innovation opportunities were adequately presented for a representation the functionality of the opportunities, but not sufficiently presented for a professional to know the exact specifications of the product or service.

The thesis covers a wide range of topics, some only touched briefly. The purpose of the thesis was to show how a systematic approach could be used to identify and evaluate innovation opportunities, therefore the level of theoretical depth was limited to serving the purpose.

6 Conclusion

We are experiencing what it called a “digital transformation”. The rapid changes in technology development have the potential to transform both business and society, opening up various opportunities. It is difficult to keep track of these changes, and how they apply.

This thesis sought to show how a systematic approach could be used to identify and evaluate innovation opportunities emerging from technology trends. The approach proved successful, and promising opportunities were evaluated. The work was carried out in a way that favoured opportunities suitable to build a business around, as such, the most promising ones were presented in a business model canvas. However, the approach could also be reformatted to fit an asset owner perspective.

The evaluated ideas that seemed to hold most potential were the autonomous drone, and predictive maintenance. What they both share in common is that companies have already started to look at similar solutions and a few have been produced. This verifies that companies see the value of these kinds of solutions. The focus area in this thesis has been on opportunities in operations and maintenance of an offshore wind farm, but some of the opportunities could also be developed for other industries.

Going forward, offshore wind farms are expected to consist of larger structures located in harsher environments, further from shore. It is of absolute necessity to reduce the total amount of work offshore, and especially unscheduled work, which carry larger costs. Various forms for remote operations are considered to play an important part as the industry matures, and as technological developments advance further. Furthermore, in a world dependent on a larger share in the energy mix coming from renewable sources, smarter grid interaction is necessary.

This thesis has proven how a systematic approach can be applied to address these needs.

For further work, the recommendation would be to especially focus on challenges and intellectual property rights, as they are areas of great importance and not sufficiently covered in this thesis.

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Appendix

The following sheets were developed by the supervisors, professor Knut Erik Bang and Muhammad Ahmad Tauqeer, and used in the identification and evaluation process:

Segment	
Value creation flow	**Process flow** What are the steps being taken to produce a product or service?
	Skills What are the key skills in the value creation process?
	Cost/cost structure What are the main cost drivers of the process flow?
Market	**Needs covered** What needs does it cover?
	Main customer groups What are the main customer groups?
Key	**Key challenges** What are the key challenges?
Other	**Other factors**

Product	
Production	**Materials/hardware** What gives it shape and structure?
	Software/programming What software/if and makes it do what?
	Cost/cost structure What are the main cost drivers of production?
Market	**Functionality** What does it provide of functionality?
	Needs covered What needs does it cover?
	Main customer groups What are the main customer groups?
Labour	**Skills** What are the key skills in producing the product or bringing the product to the market?
Key	**Key challenges** What are the key challenges?
Other	**Other factors**

Service	
Service Production	**Technologies** What are the main technologies the service is based on?
	Software/programming What software/algorithm are involved?
	Skills What are the key skills in the service delivery process?
	Cost/cost structure What are the main cost drivers of service delivery?
Market	**Functionality** What does it provide of functionality?
	Needs covered What needs does it cover?
	Main customer groups What are the main customer groups?
Delivery	**Channels** What are the main service delivery channels?
Key	**Key challenges** What are the key challenges?
Other	**Other factors**

Effect on Service of technology trend	
Service delivery	**Changes to software** – Are there possible improvements from this technology trend to the programming?
	Changes to service delivery method – Are there possible changes to the service delivery from this technology trend?
	Changes to costs – Are the service delivery costs changing from this technology trend?
Market	**Increased functionality** – Can the technology trend contribute to increased functionality?
	New needs covered – Can this technology trend contribute to covering potential new needs?
	New customer groups – Can this technology trend make the service attractive for other customer groups?
Key	**Solving key challenges** - Can the technology trend help solve one of the key challenges?
	Increased intangibility – Can the technology trend contribute to making the product less tangible/more of a service?
Other	**Other factors**

Effect on Product of technology trend	
Production	**Changes to software** ■ Are there possible improvements from this technology trend to the programming?
	Changes to hardware - Are there possible changes to the hardware/shape/structure from this technology trend?
	Changes to costs - Are the production costs changing or the cost of operating the product from this technology trend?
Market	**Increased functionality** ■ Can the technology trend contribute to increased functionality?
	New needs covered - Can this technology trend contribute to covering potential new needs?
	New customer groups - Can this technology trend make the product attractive for other customer groups?
Key	**Solving key challenges** - Can the technology trend help solve one of the key challenges?
	Increased intangibility – Can the technology trend contribute to making the product less tangible/more of a service?
Other	**Other factors**