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THESIS

«FEASIBILITY APPRAISAL OF AN OFFSHORE WIND FARM LOCATED IN GREECE»

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I would like to dedicate my master thesis to my beloved grandmother, *Panagiota Seferli-Tzivelopoulou*, who passed away three months ago. She has supported and encouraged me with her love through the best and worst years of my life.

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Ημερομηνία 31/10/2017

Abstract

The scope of this thesis is the realization of feasibility report about an installation of an offshore wind farm in the North Aegean Sea. This thesis illustrates what exactly contains a real market feasibility report, in order to convince the investors for the sustainability of an investment and the opportunity of gain profits. The next pages contain a brief presentation for the wind energy and technology inviting the reader to enter the terminology and the technology of wind farms. Apart from the literature review, there is a deep analysis of the wind industry, legislation, trends and a detailed analysis of the installation. The last chapter contains the financial analysis and deductions to defend or not the investment. For the convenience of the reader an executive summary is also provided.

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Abbreviations & Terminology

- MW →Unit of measuring power. It is equal to one million Watts.
- GW→Unit of measuring power. The Giga Watt is equal to one billion Watts.
- GWh→ Giga Watt Hour measurement of the consumption in one hour for large scale plants.
- kWh→ kilo Watt Hour is a unit of measuring the consumption in one hour and it is equal to one thousand watts in one hour.
- HVDC→ High Voltage Direct Current is the massive transmission of direct current in large distances.
- kV→kilo Volt is the measuring of Voltage and it is equal to one thousand Volts.
- IRR→Internal Rate of Return. This term is lengthy explained in second part.
- NPV→Net Present Value. The terminology is included in second part.
- CAPEX→Capital Expenditure. The term is extensively explained in second part.
- EIA →Environmental Impact Assessment.
- H&S→ Health and Safety.
- EPC→ Engineering Procurement & Constructions. The Contractor is responsible for all the activities for the project
- O & M→ Operations & Maintenance are the activities to keep the Investment in good condition through the time and unexpected conditions.
- EWEA→ European Wind Energy Association.
- EHS→ Environmental Health and Safety, mainly Guidelines.
- GIIP→ Good International Industry Practice.
- Payback Period → The time the investor needs to regain the initial capitals.
- Inflation rate→ Rising of rates-prices in a period of one year.
- Blue Economy→ Shifting from scarcity to abundance according to Pauli Gunter.

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1. Introduction

1.1 *Aim of Project*

The main aim of this thesis is considering of the realization of a feasibility report for an offshore wind farm in Greece. This thesis will defend or not the installation of this infrastructure in terms of Engineering, Ecological and Financial approach. The prices of the equipment, the rates, parameters and other characteristics are real and market based. For reasons of plagiarism, the manufacturers are not referred because it is an academic project.

1.2 *Approach and Investigation*

The first step was to make research and gain insight into wind market globally, around Europe and then Greece. Historic and market data, a market analysis and its characteristics have been taken into consideration in order to examine the barriers of entry, the big players and the Porter forces. A deep analysis of wind technology and all the new trends, manufacturers etc. are also included. After the Introduction and Literature review, this thesis is focused on the main objective; the offshore wind farm, analyzing all the fields of interest.

1.3 *Executive Summary*

The structure of the dissertation starts with general information about the wind technology. A brief historic review is illustrated. Then a basic analysis of wind technology is presented.
The literature review part contains parts for the offshore technology such as the layout of a farm, technology, wind turbines and the guidelines for an EIA Assessment.
The second part is focused on the case study of the project the offshore wind farm in Greece. This part illustrates the market analysis, the selection of the installation place, types of foundation equipment and the financial analysis. It ends up with discussion, conclusion and recommendation for further work.

1.4 *History of Wind Power*

Wind power offers a sustainable choice in the pursuit of renewable energy. Wind is generally speaking the movement of air from a region of high pressure to a region of low pressure. Wind actually exists because the sun unevenly heats the surface of our planet Earth. As long as the sun shines, the wind will blow and serve as a power source to human beings. In ancient times mariners used sails to capture the wind and start their traveling while farmers preferred windmills to grind grains and pump the water they need later on.

Nowadays, the usage of wind turbines, which are as tall as a 20-strorey building and have 200-foot-long blades and produce electricity from the wind that spinning the blades that turn a shaft connected to a generator, has raised more than 25% per year.

Wind farms have tens or hundreds of wind turbines lined up together in specifically windy spots. Wind is a very clean source renewable energy that produces that produces no air or water pollution. Mass production and technology advances make turbines cheaper as there are almost no operational costs once a turbine is erected; that is the main reason why more and more governments are interested in this alternative source of energy and offer tax incentives to spur wind-energy development.

Advantages include complaints from local people who support that wind turbines are ugly and noisy and rotating blades can probably kill birds and bats. Another important issue is that as the wind is variable, if it is not blowing there is no electricity generated. However, the booming wind energy industry proves that wind energy leading the way. In accordance with official statistics, from 2000 to 2015, cumulative wind capacity raised from 17,000 megawatts to more than 430,000 megawatts all over the world. By 2050 industry experts foresee one third of the world's electricity needs will be fulfilled by wind power.

The wind energy has been harnessed for hundreds of years. From farms in the USA to old Holland, windmills have been used to a great extent for pumping water or grinding grain. Nowadays, the windmill's contemporary equivalent - a wind turbine can use the wind power to generate electricity. Set up on a tower to seize the most energy, wind turbines, like windmills, are 100 feet (30 meters) or more above ground to exploit the faster and less turbulent wind by catching the wind energy with their propeller-like blades. Two or three blades are also set up on a shaft to form a rotor.

It is also very significant to point out that utility-scale power plants are placed close to existing power lines and in the windiest sites available. Stand-alone wind turbines are generally used for water pumping and communications purposes. Nevertheless, in windy areas, ranchers, homeowners and farmers usually make use of wind turbines as a way to reduce their electric bills. At this point, we should also mention the usage of distributed energy resources, small modular power-generating wind systems, which can be combined to improve the operation or the electricity delivery system.

1.5 *The basics of wind energy at a glance*

1.5.1 *What is wind power?*

In simple words, wind power is the ability to make electricity by using the air flows that naturally take place in the earth's atmosphere. Wind turbine blades are used to capture kinetic energy that comes from the wind and transform it into mechanical energy, spinning a generator that creates electricity.

1.5.2 *What is a Wind Turbine?*

Wind turbines are the true evolution of the classic wind mills and their purpose is to reduce reliance on fossil fuels by creating energy in a less wasteful manner - a major step towards overhauling the way we produce our energy. Wind turbines are rotating machines that can be used directly to collect and convert the kinetic energy of the wind, which pushes the blades of the turbine and spins a motor that converts the kinetic energy into electrical energy to help power the grid. As we have already mentioned before, wind is a form of solar energy and is actually a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface and the rotation of the earth.

1.5.3 *Types of Wind Turbines*

Contemporary wind turbines are divided into 2 basic groups and can be seen in design and implementation in the wind energy industry nowadays: the horizontal-axis variety and the vertical-axis design. The first and actually the most common kind is the horizontal axis wind turbine that relies on a horizontal shaft that runs perpendicular to the two or three - bladed wind turbines that are operated 'upwind' with the blades facing into the wind.

The second type is the vertical - axis design which is less common in comparison to the previous type. This wind turbine has a vertical shaft in which the blades or rotor are connected to and spin horizontally and as the gearbox and generator are more accessible the maintenance is easier.

1.5.4 *Sizes of Wind Turbines*

Utility-scale turbines vary in size from 100 kilowatts to several megawatts. Larger wind turbines are more productive in relation to their cost and are classified firstly into wind farms, which supply power to the electrical grid. Offshore wind turbines belong to the second category and as they are larger they constructed offshore, usually on the continental shelf, to harvest wind energy to generate electricity.

Single small turbines, below 100 kilowatts, can be also used to support the needs of homes, telecommunications dishes or water pumping. These systems which are called hybrid wind systems used in connection with diesel generators, batteries and photovoltaic systems are more appropriate when areas where a connection to the utility grid is not available.

1.5.5 *The three major types of wind power*

There are three considerable types of wind power:

* Utility-scale wind, which refers to wind turbines bigger than 100 kilowatts that are delivered to the power grid and distributed to the user by electric utilities or power system operators.

* Distributed or "small" wind, which actually uses turbines of 100 kilowatts or smaller to directly power a residence, farm or small business.

* Offshore wind, which are contemporary wind turbines that are set up in bodies of water around the world.

A significant milestone in the evolution of renewable energy in the USA was reached in December 2016 as the $300m Block Island Wind Farm, which in fact is the first country's operational offshore wind farm, started feeding energy into the New England grid.

1.5.6 *How wind turbines work*

When wind blows past a turbine, the blades captivate the kinetic energy and rotate, convert it into mechanical energy. This rotation turns an internal shaft that is connected with a gearbox, which raises the speed of rotation by a factor of 100. That spins in turn a generator to produce the electricity.

1.5.7 *Windmills vs. Wind Turbines*

Even if they are usually used interchangeably but there are also significant differences. Windmills in comparison with wind turbines produce only mechanical energy and not electricity. While wind turbine harness wind's kinetic energy and turn it into electricity.

1.5.8 *What is a wind farm*

Wind farm is a group of wind turbines in the same location with a view of generating electricity. Most of the times it is consisted of several hundred individual wind turbines and in fact cover an extended land of hundreds of square miles. Of course nowadays it can also be located offshore. Wind turbines usually stand together in a windy area and the whole wind farm functions as a single power plant that puts electricity onto the grid.

1.5.9 *How wind energy gets to you*

The electricity that is produced travels through the turbines of the wind farm to the power grid. Afterwards, electric utilities or power operators will deliver the electricity where there is a need. Smaller transmission lines, distribution lines, will collect the electricity generated at the wind farm and transport it to bigger network transmission lines to meet the needs of long distance locations while smaller distribution lines deliver electricity directly to your city and residence.

1.5.10 *Benefits of wind energy*

The wind is a clean, free and readily available renewable energy source which pumps billions of dollars into our economy every year, particularly into rural areas where 99 percent of wind farms are located. Furthermore, it supports thousands of well-paying and manufacturing jobs. Based on the Harvard School of Public Health, wind power produces billions in public health savings (only $7.4 billion produced in US in 2016) by decreasing pollutants that create smog and cause asthma and other lung diseases. In accordance with the American Lung Association "Transitioning to clean energy protects all people from the harm of air pollution".

1.5.11 *What is wind industry*

The wind power industry is a modern term which describes the industry that is involved with the design, manufacture, construction and maintenance of wind turbines.
It all began in 1979 with the serial production of wind turbines by Danish manufacturers Kuriant, Vestas, Nordtank and Bonus. Nowadays, it is undergoing a period of rapid globalization and consolidation all over the world as more and more large companies are interested in investing in wind power.

1.6 *How wind energy works*

Contemporary wind farms are an evolution of traditional windmill. A collection of wind turbines in one location is referred to as a wind farm. There are actually 4 key parts to a modern wind turbine: the foundations, the tower, the nacelle and the blade assembly.

The turbine is set on a steel reinforced concrete **foundation** which is always below ground level and not visible since construction is finished. It is especially designed to ensure the turbine withstands very strong winds. **Towers** are usually constructed from tubular steel but some other times turbines have lattice towers. Steel towers are mostly painted a light, non-reflective paint that assists in blending better into the background. **The nacelle** is positioned at the top of the tower and contains the generator and other components of significance importance like the gearbox and control equipment. An anemometer and a wind vane are put on top of the nacelle, as well. Nowadays, most wind turbines have got 3 **blades** or less commonly 2 ones, made from fiberglass, carbon fiber or wood laminates. They also rotate around a central hub on a horizontal axis.

1.6.1 *Generating Electricity*

Wind turbines produce electricity by using the natural power in the wind. The rotating blades, which are like an airplane wings, turn a shaft inside the nacelle that goes into the gearbox which raises that rotation speed for the generator which in turn uses magnetic fields to transform the rotational energy into electrical energy. On the other hand, there are some turbines that use direct drive technology. In this way, the rotating hub is connected directly to the generator whose produced electricity goes via cables to a transformer and then to the wind farm's substation in order to be converted into the right voltage for the grid or local network.

In addition, wind turbines can also change their direction through motors which turn the nacelle and the blades along with it in order to face into the wind. This movement is called yaw. To ensure the optimal amount of power that can be extracted from the wind, the blades can also pitch or angle.

Part 1: In-Depth Explanation of Wind technology and Industry

2. Literature Review

2.1 *Deep Water Offshore Wind Technologies*

This thesis paper is about the importance of using the ocean's seabed as the foundation of an offshore wind farm as well as the prospective benefits to offshore wind energy. The usage of onshore wind turbines has created a growing trend toward production of electricity, despite the current drawbacks. It is true that the wind potential on land is not as high as on the sea while the creation of visual hindrance and the noise that is made by the rotation of the blades can be annoying to local residents.

The solutions that are emerged give particular emphasis on a cautious analysis of sites in order to minimize the impact on the local environment. Offshore wind turbines are established in places where there is little possibility for human living; as a result, no visual or noise issues are raised. The lack of naturally or unnaturally created (man-made) hindrances does create the possibility of higher electricity from the turbines because of the undisturbed air path flow and wind velocity.

The main scope of the project was to design a 400MW deep-water offshore wind farm that can have the capability to use the wind resource placed on sea conditions. Afterwards, it refers to studies regarding the location and the potential wind source of the wind farm, and any environmental consequences that could be come from the installation of the wind farm. Research has also made concerning the necessary economical components needed for the operation of an offshore wind farm in comparison with a brief look into the future technologies that will be used for wind turbines. The paper then ends up presenting the reasons that explain why the Aegean Sea was chosen as the most appropriate site for building the wind park. Furthermore, this thesis paper indicates that deep-water technology is not only well developed when compared with onshore wind technology and states that even if the potential offshore wind resources are greater than onshore wind resources the offshore technology is far more costly.
Based also on the final results of this paper, the proposed wind farm would be roughly 0.098 EURO/kWh while the cost for the construction of the present largest offshore wind farm (Horns Rev) was at the price of 0.49 EURO/kWh.

2.2 *Deep Water – The next step for offshore wind energy*

The European Wind Energy Association compiled a report in July 2013 clearly stating that *"Europe's seas and oceans are rich in opportunities and sources of employment for our economy"* (EWEA, 2013). The target audience of the above

words was mainly those people who are in positions of political influence. The offshore economy or the “blue economy” gave employment to 58,000 people in 2012 while at the same time it has the potential to decarbonize the present electricity system.
The information that is depicted in the current report is based on the research done by the ‘Deep offshore and new foundation concepts’ Task Force, a part of the European Wind Energy Association’s Offshore Wind Industry Group. Firstly the appropriate data collected and afterwards evaluated by the Task Force which also produces the required steps that are actually suggested to be of use in large-scale development of an offshore wind farm.

Some substantial challenges are still involved in the offshore industry. But political and economic support is not adequate to allow for large scale growth. However, the data from the repost points out that offshore wind energy is one of the faster growing sectors in the maritime industry. *“It’s installed capacity was 5 GW at end 2012, and by 2020 this could be eight times higher, at 40 GW, meeting 4% of European electricity demand”* (EWEA, 2013). Offshore wind energy could meet roughly 14% of the EU’s total electricity demand if the predicted progress goes on at the same rate.

A supportive legislative framework and development of new offshore designs are matters of great priority to continue to back up the substantial growth concerning the offshore wind industry. The continued pressure for progress in this field will probably allow the industry to tap into the full potential of the wind resources that are available in the Atlantic, Mediterranean and the deep North Sea waters. Present structures are restricted to ocean depths of 40m – 50m.

The final analysis that completed by EWEA leads to the following results: to unlock the full potential of the offshore wind energy mark in the Atlantic, Mediterranean and deep North Sea Waters, deep offshore designs are needed for this purpose. This sort of use will constitute an export chance for an assortment of countries. The increase of the capacity of the deep offshore industry can then result in the development of expertise, skills and the technologies that are developed in Europe and exported to other nations all over the world including the US and Japan. In addition, any energy that is generated from the turbines placed in the deep waters of the North Sea can actually meet the EU’s electricity demand four times over.
Furthermore, deep offshore designs have a competitive Levelized Cost of Energy (LCOE) as the turbines have bottom fixed foundations that placed in more than 50m water depths. For that reason, political economic and technical challenges should be overcome by the industry to achieve commercial and large-scale success with respect to the technology. When the previously stated challenges are solved, it is possible for the first large-scale wind farms to be installed and grid connected by 2017.
The data represent that deep-water offshore wind farms are possible and up to 40m currently are also viable, based also on the data originates from EWEA, even if the waters of the Bahamas are typically 15m – 30m deep.

Figure 1: A Deep-Water offshore wind Farm in Scotland (The Telegraph)

2.3 *EIA Guide to offshore wind farms*

The EIA Guide was created by the Crown Estate to break down costs and stages that involved in the development of an offshore wind farm. The components of an offshore wind farm substation, the necessary installation efforts, the development process and the operation factors that involved regarding the maintenance of a wind farm are considered, too. The goal of this report is to "*help them (companies and political figures) realize the opportunities that will arise from the anticipated £75 billion investment over the next decade"* (The Crown Estate, 2014). Moreover, associated challenges of scale, water depths and distances from shore have still not been solved with an optimal solution or predict the accuracy of which technologies and processes will actually be used for each of the stages. *"The pace of innovation in the wind industry has been rapid by any standards over the past decade (at the turn of the new millennium few saw the prospect of 5 MW machines with rotor diameters over 120m"* (The Crown Estate, 2014).

"Rounds" are called the stages when building an offshore wind farm. The first round is the design stage; the second is the construction stage while the third one regards the operations stage. Because of the variability of the third round, there isn't actually a standard figure that can be used. The report states "For the purposes of this document, we have assumed that the zones will be constructed in blocks of around 500 MW at around 50 miles from shore, and we will use this to inform our judgments on the cost and processes used" (The Crown Estate, 2014).

3. Background Information of Offshore Wind Farms

3.1 *Development of wind power*

More than 2000 years ago the first man-made development of rotating wind power machines began globally but mainly in Chine and Iran. These technical developments were later used for the creation of wind turbines which in turn leaded to generation of electricity in the late 19th century. The three most significant wind turbines were: *"a horizontal – axis wind turbine (HAWT) in the United States in 1883 (the Brush turbine), a vertical – axis wind turbine (VAWT) in Scotland in 1887 (the Blyth turbine) and a HAWT in Denmark in 1887 (the la Cour turbine)"* (Tavner, 2012).

In Germany, Russia and the United States were the countries where the large electric power wind turbines (>100kW, >1MW) were created in the 1930s and 1940s. Contemporary large wind turbines developed in Europe and the United States during 1970s and 1980s because of the encouragement of the European Union and the US department of Energy experimental programs. But the main reason was the war in 1973 among Egypt, Syria and Israel which leaded to the oil prices increase.

The final design elements of the turbines were influenced by the horizontal axis wind turbine designs and other design configurations after competing with the vertical axis wind turbine. Due to the poor efficiency ratings from older designs, the trial and error stage was a significant piece of the creation of a standard wind turbine design. Electricity generation continued to increase in conjunction with the efficiency rating as wind turbine development was in progress.

During 1985 the reliability of wind turbines in Europe become more industrial as it was motivated by the German and Danish wind energy economy along with the development of wind farms in the United States in 1973. In the Netherlands during the 1990s there were concerns concentrated on the offshore wind farms and the maintenance that would be involved to ensure high wind turbine availability. It was believed this development would be a form of low sustainable energy able to compete with fossil fuels in the wind turbine market.
Concerning larger onshore turbines (>1MW) relied on the performance ratings that gained by the Danish Concept the production of energy has now an operational availability of >98% *"and in the mean time between failures (MTBFs) of >7000 hours, which is a failure rate of just over 1 failure(s)/turbine/year, where a failure could be described as a stoppage with a duration of 24 hours"* (Tavner, 2012). It is sure that there is room for greater improvement in the wind turbine industry which is being addressed as sustainability becomes a global effort.

3.2 *Large Wind Farm development*

In the late 1970s and early 1980s the usage of large wind farms started to become more intensive as a way of gaining more power from wind resources by assembling wind turbines in a specific geographical indication. One of the first large wind farms was built in California in the 1970s and utilized small wind turbines arranged in an array of 100 turbines collectively. Utilizing wind turbines in a farm means higher electrical output and reduced long-term costs as it is covered by the shorter payback period which is generated by the produced amount of electricity.

The correlation between the reliability of the machines and the costs have not technically tested but it is accurate to mention once the reliability of a device is increases to a certain standard the total chances of the machine breaking down reduces to such an extent that there is less down and more utilized time for the generation of electricity.

The visual impact on local human life is one of the most significant drawbacks of large wind farms, especially in highly populated countries like the United Kingdom due to space, visual impact and noise amenity. *"In general, while large wind farms have been established in the United States, Spain and Northern Germany, they are not common in the United Kingdom where the planning process has militated against the concentration process"* (Tavner, 2012).

Whitelee Wind Farm is the largest on-shore wind farm in the United Kingdom with 215 Siemens and Alstom horizontal axis wind turbines and a total capacity of 539 MW. The Gansu Wind Farm project is a large onshore wind farm in the western Gansu Province in China in the desert areas near the city of Jiuquan which is expected to reach 20000 MW by 2010 at an estimated cost of $ 17.5 billion (Chen, 2009) (Watts, 2012). The construction phase was split into three sub-phases: the first consists of the construction of eighteen 200 MW and two 100 MW wind parks. The second comprises the construction of forty 200 MW wind parks.

The scheduled capacity of the wind farm whose construction started in August 2009 is 5,160 MW by 2010, 12,700 MW by 2015 and finally 20,000 MW by 2020 (Chen, 2009). In 2008, the construction began on the 750 kV AC power line that would be used to carry the electricity from the wind farm while construction of the wind farms themselves actually began in August 2009 (Lim, 2009). Since March 1, 2012, a wind power coordinated control system was put into effect to adjust the production of the 18 wind farms of the Gansu Wind Farm Project, which sums 10 GW, to meet the needs of the transmission grid that is restricted to 1.5 GW. However, due to local-government partiality toward coal and inadequate long-distance transmission, Gansu nowadays has got some of the highest rates of underutilization in the wind sector in China (Hernández, Javier C. 2017).

3.3*Offshore Wind Farm development*

Near Fyn Island 11 wind turbines were established in Baltic waters in in 1991 in Denmark, Vindeby establishing one of the first offshore wind farms. In tidal waters inshore at Blyth (Northumberland, United Kingdom) near the North Sea in 2001 a small offshore wind farm of 2 wind turbines was installed.

Another much significant wind farm was set up in Denmark in 2000 at Middelgrunden near Copenhagen with 20 Siemens SWT1.0/54 WTs.

All these projects greatly prove that operating a wind turbine on the coastline is not only possible but much successful as well.

3.4 *Overview of Offshore Wind Farms in Northern Europe*

In the Baltic Sea the wind farm development was much promoted due to the lack of tidal conditions even if ice and wave environments are possible to be dealt with during the year. After the Middelgrunden wind farm, many farm projects started in Nysted, Dnemark, in Lillgrund, Sweden and in Rodsand, Denmark.

Furthermore, after the successful installation at Blyth, in the United Kingdom, the Crown Estate started the licensing process regarding the UK offshore wind farms which would occur in three rounds. Giving more attention to the first round, allowing 25-30 wind turbines per wind farm, developers, installers and operators could get the experience they needed and also have the opportunity to handle the new type of machinery.

Denmark accelerated its wind farm process in calmer waters which leaded to a success as the size of offshore wind farms largely increased in the North Sea. But when operational issues arose, the type of designs used in offshore wind turbines had to be changed; therefore, the equipment that manufacturers and developers of North Sea should be re-evaluated and as a result the development slowed down.

Concerning the UK Round 1, wind farms turbines reached more than 50 the development speed was reduced. That information was leveraged leading to Round 2 allowing the sites to achieve 100 wind turbines. The Belgian, Danish and Dutch developers having learned from the past trends they applied this knowledge to their newer wind farms which led to increase the installation speed.

As regards Round 3, wind farms are actually to hold a much larger capacity of wind turbines ranging from 300-600 concerning the UK. Based on the UK Offshore Energy Strategic Environmental Assessment in January 2009, 33 GW of possible offshore wind energy can be produced and help the UK to meet its 2020 energy demand.

The main purpose of Crown Estate's program is to back up the UK's offshore renewables industry, to contribute to energy security objectives by generating revenue for the good of the nation.

The environmental analysis revealed that 9 sites in the United Kingdom that will deliver the capacity needed to be categorized it as a Round 3 site. After publishing the final analysis, there were a few renewable energy developers that started to exclusively bid to get the rights to develop in the defined zones. The development partners that are to be involved in the projects were announced while at the same time eight of these projects are currently under development.

The companies involved in the development of the wind farm projects while cooperating with investors they are also undertaking environmental and engineering studies to gain the approval of the Crown Estate. Once the consent is given it will need then to *"obtain the necessary statutory consents before progressing with construction"* (The Crown Estate, 2010).

3.5 *Overview of Offshore Wind Farms in Major Continents*

Block Island Wind Farm is the first commercial offshore wind farm in the United States. It is a five wind turbine park established near Block Island, Rhode Island in the Atlantic Ocean. (Cardwell, 2015). The 30 MW project was developed by Deepwater Wind. Construction in fact started in 2015 and in late summer 2016 five Alstom Haliade 150-6-MW turbines were erected; but operations were launched in December 2016 (Alstom, 2015).

The Block Island wind farm is set up about 3.3 nautical miles southeast of Block Island and is expected to produce more than 125,000 MW hours per year. Power is transmitted from the turbines to the electric grid via a 34 km submarine power cable buried under the ocean floor. The whole structure designed by Alstom Wind stand 600 ft and can withstand a Category 3 storm. This specific system connects New Shoreham to the grid allowing ceasing the usage of diesel generators. The 100-turbine project could provide 1.3 (TW h) of electricity annually while the foundations were designed by Louisiana-based Keystone Engineering Inc. to withstand a 1000-year storm. The wind farm started its commercial operation in December 2016. Earlier there was a project created by Fisherman's Energy to build a 25MW offshore wind farm off the coast of New Jersey which was finally rejected in 2015 by the Public Utilities Commission (PUC).

Figure 2: Block Island Wind Farm (Treehugger)

3.6 *Economics and Terminology of Offshore Wind Farms*

The definition that is set by the International Electro-technical Commission (standard IEC 61400-Pt 26) supports that a wind turbine generating system is *"converting wind energy into electrical energy and/or providing reactive compensation"* (Raben, 2010). The two availability definitions that have been taken based on the UK DTI (Department of Trade and Industry) and BERR (Department for Business Enterprise and Regulatory Reform) are the:

A) Technical Availability, which symbolizes the amount of one wind turbine or wind farm that is able to generate electricity in the form of a percentage.
B) Commercial Availability which is mentioned to be *"the focus of commercial contracts between wind farm owners and WT OEMs (*Wind Turbine Original Equipment Manufacturer) *to assess the operational performance of a wind farm project"* (Tavner, 2012).

The commercial availability of a wind turbine will always be at a higher rate compared to the technical availability because of the existence of more acknowledgements of downtime for the technical availability (Tavner, 2012) (Raben, 2010).

This actually leads to one of the main issues that rose regarding offshore wind, which has to do with availability, 'A', is stated to be influenced by wind speed and time, *'A (u, t)', 'u'* (Faulstich, 2011).

3.7 *Roles involved in Offshore Wind Farms*

3.7.1 *Stakeholders*

To have a functional wind farm there are a variety of individual and group roles that are necessary. Among others, stakeholders are those who begin the project but also set in place the objectives of the company that has the responsibility for the wind farm. These objectives give the wind farm the guidelines to deliver reliable electricity at competitive prices providing a reasonable return for the stakeholders.

3.7.2 *Regulators*

In the United Kingdom regulators are the individual(s) that are responsible for setting the market landscape for the offshore wind farm. Offshore Transmission Operators are in charge of making sure that the offshore wind farm project is connected with the onshore transmission grid via safe and secure means.

3.7.3 Investors of the Wind Farm Project

Banks, landowners and energy companies are the usual types of investors for offshore wind farm projects. The Crown Estate in the UK has licensed specific offshore areas appropriate for wind farm development (Tavner, 2012). Availability, stability and the reliability that wind energy can generate are some of the most important issues for investors because via the avail of these aspects they can receive their return on the investment. Due to the fact that renewable energy is not as commercially explored as oil and gas the technical difficulties often have to be thoroughly explained and similarly the exact area where their investment can be placed to be defined, as well.

3.7.4 *Certifiers and Insurers*

The certifiers have the responsibility for making sure that the offshore wind turbine designs and the needed offshore structures are up to a specific standard. The project insurers have to ensure the necessary steps are taken to insure the wind farm project specifically in case it is a large project. The regulation and insurance policies can be often cohesive as they have to make sure that certain health and safety standards are upheld regarding the installation and operation stages and the individuals' life is as little as at risk is possible when working on the site. It is significant to be seriously taken as the offshore environment presents more complicated scenarios to be dealt with comparing to the onshore environment.

3.7.5 *Developers*

The developers of an offshore wind farm are the associates of those involved with the project and their main target is to be sure that the project is able to create a return on the electricity generation assets that are sold to the operators like the electricity generating companies and those who are getting involved in the transmission process, as well. Due to the size and detail of an offshore wind farm asset, their job is also to get other investors involved in the development team especially in places that there is the need for financial expertise to make them understand the issues that need to be addressed.

Another major part of the instillation, deployment and operation of an offshore wind farm project are the factors that are involved in the marine installation assets. Port and docking for any needed marine craft, installation and maintenance vessels, infrastructure and manpower that will be necessary for managing and operating the previously stated factors are also included. These kinds of issues can be efficiently resolved via marine engineering companies/firms that have naval architects and marine engineers who are specialized in the offshore industry.

3.7.6 *First Party Equipment Managers*

There are people who are in charge of any equipment that belongs to the wind turbine operation equipment and whose essential role in relation to the mixed-activity that is taken place is to ensure that the project include onsite manpower enough to provide a degree of sustainability.

3.7.7*Asset Managers and Operators*

When referring to an offshore wind farm, operators are those who could provide the electricity into the main onshore grid. They usually have generators that are fossil fuelled, nuclear fired and of renewable generation. In most recent cases, the new offshore wind farms have designed their electrical output to be compatible with present onshore electrical generation such as onshore wind and oil & gas.

3.7.8 *Maintainers/Field Engineers*

In the wind farm project the maintainers are actually placed in various positions. Because of the size of the project a large number of experienced maintainers who are well-trained are responsible for maintaining the wind turbines.

They have access to current data concerning the condition of the wind farm and of each individual turbine, as well. Through prototype testing information, supply chain tests and also production data the maintainers can also have information of the development stages of each turbine (Tavner, 2012). Those who work with the staff are also well-trained to use the wind turbine and fully understand the faults and issues regarding each individual wind turbine. This specific data is not only practically useful during the installation period but also throughout the operation period of the wind farm because if any issue arises, the maintainers will have the knowledge of the procedures needed to resolve any problem.

4. Selection, Design and Construction Process of Offshore Wind Farm

4.1 *Design Process*

The design procedure about an offshore wind farm firstly involves the initial site selection. Afterwards, it is followed by a critique and assessment of related external conditions and factors. The assessment considers the wind turbine size section, any geological dangers that the area may present an investigation of subsurface activity, the design of the load cases, support and foundation structure design and selections and finally a geotechnical and structural analysis (Malhotra, 2011). Mass production of wind turbines for a farm is encouraged from the side of the investing company to achieve economies of scale, unless it is a small farm made for research purposes. Once the site selection has taken place, it is up to the designer to choose one of the predefined turbine class types that best suit to the chosen site.

Because of the complicated variability that accompanies the offshore environment, the foundation design must be predesigned for the site. Factors that are taken into seriously account when engineering the foundation for the offshore wind turbine are the water depth, seabed conditions, wave heights, current velocities and ice climate. Regarding the foundation of the turbines, the factors that are really considered include the design loads, site geology, water depths and environmental impact. An integrated analytical model for the turbine, support structure, foundation system, site specific wind and wave regimes will be carefully calculated or researched in case of a large offshore wind turbine type.

4.1.1 *Wind Turbine Design: Basic Load Considerations*

The strength, the dynamic behavior, the fatigue properties of materials should be taken into seriously consideration when referring to building wind turbines.

4.1.2 Extreme Loads (Forces)

Generally speaking, wind turbines are built to catch the wind's kinetic energy. Turbines do not have many blades or very wide blades because in case of a wind that blows at a hurricane speed turbines will be liable to very large dangerous forces. Of course wind turbine manufacturers should be in position to certify that their turbines are built to withstand extreme winds.

On the other hand, to reduce the influence of the extreme winds turbine manufacturers turbines with a few, long and narrow blades are most preferable. Furthermore, to make up for the narrowness of the blades dealing with the wind, turbine manufacturers choose to allow the turbines to rotate relatively fast.

4.1.3 Fatigue Loads (Forces)

If wind turbines are set up in a very turbulent wind climate they can become liable to fluctuating winds and therefore to fluctuating. Components which are subject to recurring bending, such as rotor blades, might develop cracks after some time which finally might create the component break. For example, the enormous German Growian machine (100 m rotor diameter) should be put out of service after less than three weeks of operation due to metal fatigue which was not an appropriate material for rotor blades.

It is of great importance to estimate in advance, when designing a wind turbine, how the different components are going to vibrate, both individually and jointly, and also to calculate the forces that are involved in each bending or stretching of a component.This is liable to structural dynamics where physicists have developed mathematical computer models that analyze in depth the behavior of a whole wind turbine. These models are specially used by wind turbine manufacturers to design their machine in a safer way.

4.1.4 Structural Dynamics: An Example

A 50 meter wind turbine tends to swing to and fro every three seconds. The frequency with which the tower vacillates back and forth is also known as the eigenfrequency of the tower. The eigenfrequency relies on both the height of the tower, the thickness of its walls, the type of steel and the weight of the nacelle and rotor.

The rotor will push slightly less against the tower each time a rotor blade passes the wind shade of the tower. In addition, the rotor might either be made slightly wet or reinforce the vacillations of the tower.

The rotor blades themselves are also flexible and may tend to vibrate once per second. It is very significant to know the eigenfrequencies of each component to design a safe turbine that has few possibilities to oscillate out of control.

4.2 *Site Selection*

When the wind conditions are potentially viable for the chosen site, specific factors that are included in the site selection are processed. The factors that are part of the site selection is the proximity to deliver electricity to the demand site, concurrence to electricity distribution companies included, an environmental impact analysis that presents the degree of the project affecting shipping and fishing routes and dredge channels, any affects that the wind farm installation and operation has on the telecom installations and the distance from the site to any airports and the wind farm's effect on airplane routes (Malhotra, 2011).

Because of the complexities and an assortment of downfalls that may arise during the development of an offshore wind farm, to predict and solve such kind of issues an extensive study should be done. For example, an environmental impact study phase that needs public involvement while using permitted process time which will require input from stakeholders including fishermen, local communities, airport and marine authorities and a local engineering consultancy.

The process usually becomes faster after allowing the public to have access to progress data. The visual impact will be reduced when choosing a site that is further from the shore. Installation complications are also diminished in case the collaborators involved with the grid connection are chosen and are updated accordingly during the project. Prior consciousness and analysis of any possible grid connection areas to design and improve substation locations and cable connection routes is necessary for gaining the approval of the public. The development of a high performance plant will mean that compatibility analysis between the grid and the wind farm will need to be done as to avoid system downtime throughout operation.

Furthermore, when interested in finding an appropriate wind turbine site, looking at nature itself is usually an excellent guide. Trees and shrubs in the surrounding area can give much valuable information about the prevailing wind direction. In addition, in case of moving along a rugged coastline, centuries of erosion that have worked in one particular direction can also give trustworthy data, too. In relation to a wind rose that is estimated over 30 years, the meteorological data that comes is helpful but most of the times are not collected directly at the site we are interested in. That's why this issue would be of our primary interest and be careful with the use of meteorological information. On the other hand, if there are already wind turbines in the area we are examining in detail, their production results could become an excellent guide as for local wind conditions. Manufacturers in Denmark and Germany with great experience regarding wind turbine sites can offer guaranteed production results relying on wind calculations made on the site.

4.3 *Farm Layout*

A wide and open view towards the prevailing wind direction is a goal of primary interest. When having only few obstacles to deal with and a low roughness in the same direction while looking for a rounded hill to place the turbines it is much possible to get a speed up effect in the bargain.

A variety of wind turbines that set up in the selected site which each is connected by a set of cables that lead to an adjacent offshore transformer station is actually included in the standard layout of commercial off shore wind farms. Afterwards, the offshore station is then attached to an onshore station via an external underwater sea cable that lets the onshore station connect to an existing power grid. The wind turbines are placed up to a lateral distance of 8 times the rotor diameter between them.

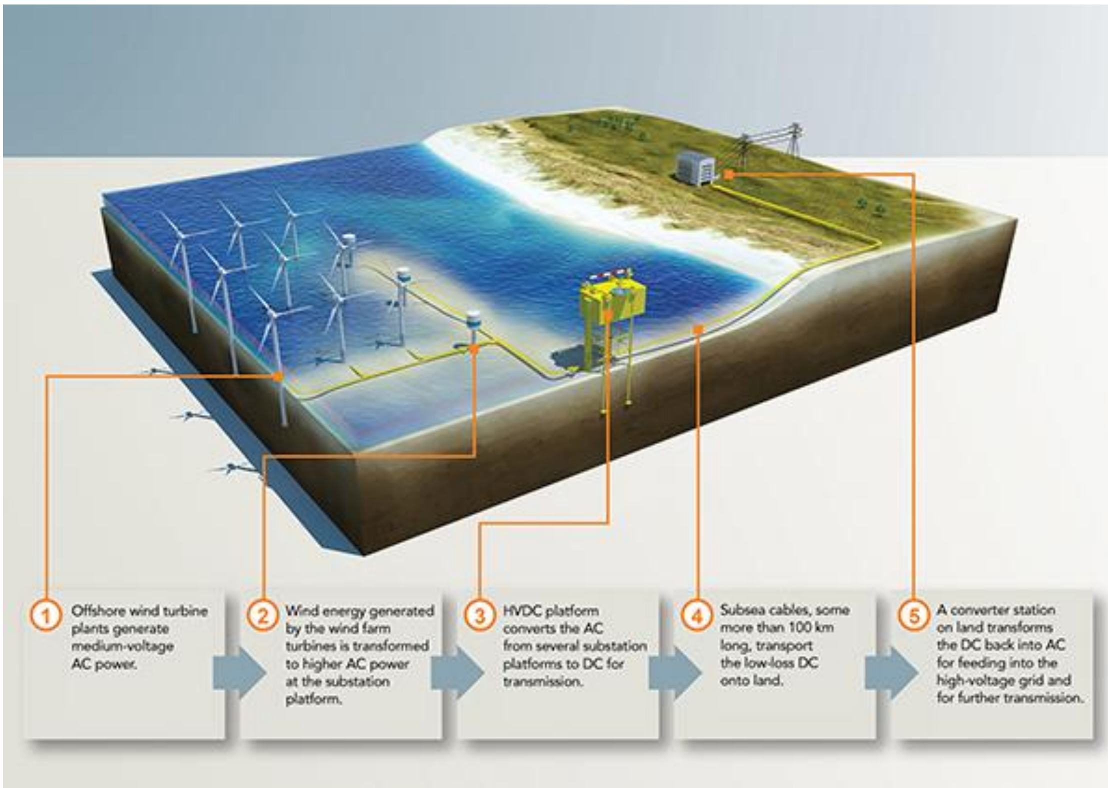


Figure 2: The Layout of a Typical Wind Plant (TDWord)

A variety of wind turbines that set up in the selected site which each is connected by a set of cables that lead to an adjacent offshore transformer station is actually included in the standard layout of commercial off shore wind farms. Afterwards, the offshore station is then attached to an onshore station via an external underwater sea cable that lets the onshore station connect to an existing power grid. The wind turbines are placed up to a lateral distance of 8 times the rotor diameter between them.

In this case the cost for cables can be reduced but the turbulence will be increased and also wake effects that the turbine has to endure, too. Utilizing the collected site information and performing a layout parameterization an engineering consultancy will make use of in order to arrive to any optimal farm layout. The analysis will be done using site information research and a combination of modeling tools.

The results will lead to calculating the ideal width of separation among the farms, the size of the space in the centre of the wind farm that will be effectively concluded, the succinct amount of turbines that will be necessary for the farm layout, the individual positioning of each turbine and the shape of the layout for the farm, as well.

4.4 *Turbine Components*

The nacelle, the rotor blades, the tower, the transition piece, the support and foundation are included among the main components of an offshore wind turbine. The rotor blades and nacelle are the most important wind converting components that take on incoming wind speeds and transform them into electricity via a turbine unit placed inside of the nacelle chamber, as we have already mentioned before. The tower holds the nacelle structure and is connected to the transition piece that holds a small platform for maintenance workers to use. Rolled steel is used for the tower and transition piece as it is specifically made for the rotor blades' weight and the nacelle. The foundation that is made of materials depending on the site requirements is strong enough to keep the structure supported and capable of withstanding waves and wind, too.

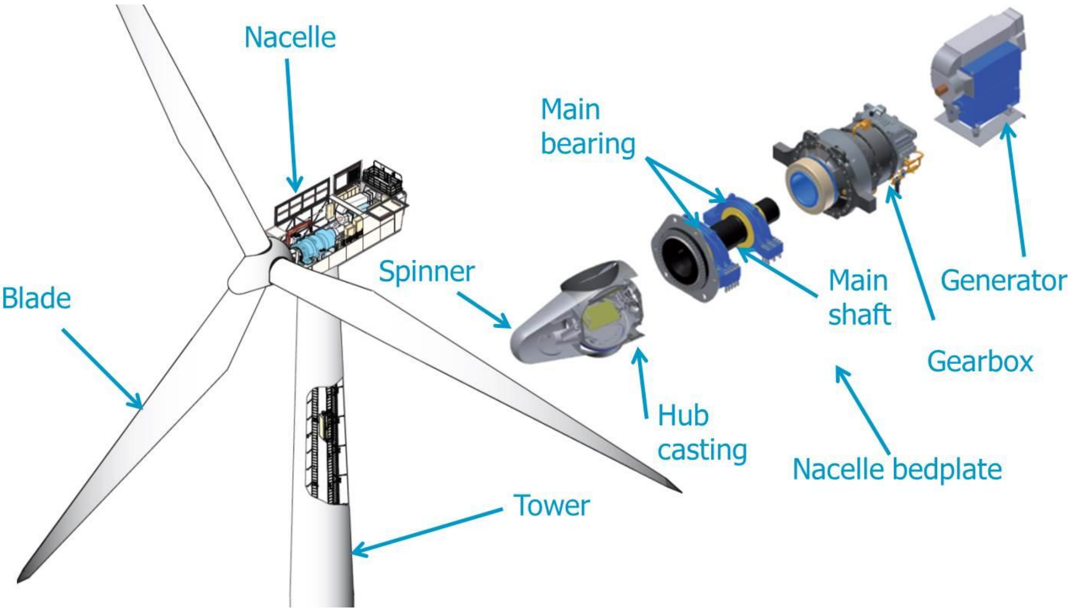


Figure 4: Main Components of an Offshore Wind Turbine (Kent Wind Energy)

4.5 *Turbine Operation*

When air starts to flow through the rotor blades, it obliges them to rotate transferring the kinetic energy from the wind into mechanical energy. The mechanical energy is then used to drive a shaft through which a gearbox is then used to give power to a generator in the nacelle which creates the current using electromagnetic induction. In addition, the nacelle has the capability to turn vertically to face the force if the wind direction changes. Afterwards, the electricity that is created is sent to the transformer, established at the base of the turbine, where it is then converted to a higher voltage for suitable usage. *"The power that can be harnessed from the wind is proportional to the cube of wind speed up to a theoretical maximum of about 39 percent* (Malhotra, 2011). To avoid any structural damage, the technical designs of current wind turbines only allow functionality up to a certain wind speed. *"So far, it is considered cost optimal to start power regulation at 10-min wind speed of 9-10 m/s, have full regulation at mean wind speeds above 14-15 m/s and shut-down or idle mode at 25m/s"* (Malhotra, 2011).

The usage of power regulatory system will let an increase in electricity output stability throughout a variety of load conditions while giving the total system wider availability. Regulating the pitch of the blades along with the movement of the wind, an increase in the system output stability can be also made. Due to the wind forces the yaw of the wind turbine can vary every 30s to 60s depending on the size of the turbine which create gyroscopic loads.

Non-linear aerodynamics can be created thanks to the resultant effects of the pitching and yawing of the turbine and affect the performance of the turbine to fully analyze the performance of the turbine and correct any problems that might arise; because of these conditions it should probably be modeled into the turbine response systems.

4.6 Wind Turbine Foundation Requirement & Dynamics

Wind turbines foundations should withstand any deformation based on operation data given by the turbine's manufacturer. The tolerances of the foundation are a maximum allowable rotation at the pile head when installation is complete. There is also a maximum permanent rotation from the cycle loading over the wind turbines' operational life. 0.5degrees (0.009 radians) for an offshore wind turbine is the maximum tilt. The permanent tilt that is created by the construction had to be subtracted from the tolerance specifications.*"Typical values of construction tolerances range from 0.003 to 0.0044 radians (0.20 degrees to 0.25 degrees)"* (Malhotra, 2011).

The dynamics of the foundation is an important aspect of the offshore wind turbines' structure, as the foundation must be designed accordance with the maximum vibrations which are created by the rotation of the blades. For a three bladed rotor, when it starts to resist forces of 1P and 3, where in this case P is the blade passing a frequency. *"For a typical variable speed turbine, the blade passing frequency is between an approximate range of 0.18 Hz and 0.26 Hz and rotation frequency, which is between about 0.54 Hz and 0.78 Hz"* (Malhotra, 2011 &Gaythwaite, 1990). Sea waves create frequencies from 0.04 Hz to 0.34Hz and to avoid unwanted resonance, a different natural frequency must be designed.

A larger wind turbine diameter will lead to taller tower designs and heavier nacelles; in this case, the foundation will have to be suitably designed with following these aspects in the design. As the height of the tower rises the foundation's design will proportionally change, the physical demand of the foundation will increase. Most wind turbine towers are designed to be rigid to reduce the effects of vibration. The stiffer a tower is made to be, the more materials will be required in the construction phase. It is up to designers to plan the necessary amount of stiffness through turbine manufacturer data to balance the required rigidity with the financial budget of the turbine.

5 General Information for Environment, Safety and Health for Wind Technology

5.1 *Environmental Impact Assessment-EIA*

The Environmental, Health and Safety (EHS) Guidelines are technical reference documents that include general and industry exact examples of Good International Industry Practice (GIIP). These EHS Guidelines are applied as obligatory by their relevant policies and standards when one or more members of the World Bank Group become involved in a project. **General EHS Guidelines** are used along with these industry sector EHS Guidelines which provide the requisite guidance on common EHS issues possibly practicable to all industry sectors. Multiple industry sector guidelines may be indispensable in case of compound projects.

The EHS Guidelines comprise the performance levels and measures generally achievable in new facilities by current technology at affordable costs. The establishment of site-specific goals with a suitable timetable for accomplishing them may be involved while the applicability of particular technical recommendations should be founded on the professional view of qualified and well experienced persons. When host country regulations are different from the levels and measures displayed in the EHS Guidelines, the more stringent is followed giving priority to human health and the environment.

5.1.1 *Applicability*

The EHS Guidelines for wind energy contain information relating to environmental, health and safety aspects both on onshore and offshore wind energy facilities that should be applied during the construction and all operational stages. EHS issues connected with the construction and operation of transmission lines are taken into consideration in the **EHS Guidelines for Electric Transmission and Distribution.**

5.2 *Environment*

Construction activities for wind energy facilities usually contain among other things, land clearing for site preparation and access routes, excavation, blasting and filling, transportation of supply materials and fuels, installation of overhead conductors or cable routes (above ground and underground) and more. Decommissioning activities may include removal of infrastructure project and site rehabilitation.

Environmental impacts connected to the construction, operation and decommissioning of wind energy facilities may have an effect on the physical environment (such as noise or visual impact) and biodiversity (influencing bats and birds, for example). The transport of equipment and materials throughout construction and decommissioning might appear logistical challenges (e.g., transportation of long, stiff structures such as blades and heavy tower sections) because of the typically remote location of wind energy facilities. Recommendations for the management of such EHS issues are included in the construction and decommissioning section of **the General EHS Guidelines.**

The construction of access roads for the siting of wind facilities in distant locations may lead to additional risks. **The Toll Roads EHS Guideline** supplies significant guidance on prevention and control of impacts connected with the construction and operation of road infrastructure.

Environmental issues, among others, include Landscape, Seascape and Visual impacts, Noise, Biodiversity, Shadow Flicker and Water Quality, as well. Cumulative environmental and social impacts could be related to the nature of wind energy facilities. International sources of good practice guidance can be used in case there is no relevant country-specific guidance especially when the wind energy facilities are sited in close to regions of high biodiversity value.

5.2.1 *Landscape, Seascape and Visual Impacts*

A wind energy facility could have an impact on viewscapes depending on the location. Visual impacts that are connected with wind energy projects commonly concern the installed and operational turbines themselves (e.g. color, height and number of turbines). Impacts on Legally Protected and Internationally Recognized Areas of importance to biodiversity and cultural heritage features should be greatly considered to avoid affecting the character of the surrounding landscape and /or seascape.

Avoidance and minimization measures to deal with landscape, seascape and visual impacts are related to a great extent with the siting, layout of wind turbines and associated infrastructure (such as meteorological towers, onshore access tracks and substations). Turbine layout, size and scale regarding the surrounding visual receptors and landscape and also seascape character should be taken into account.

Attention should also be paid to the closeness of turbines to settlements, residential districts and other visual receptors to keep visual and impacts on residential amenity at the minimum where it is possible.

Some other factors that can be taken into seriously consideration to diminish visual impacts, among others, are to embody community input with wind energy facility layout and siting and to maintain a uniform size and design of turbines (e.g., type of turbine and tower, as well as height).

To adhere to country-exact standards for making turbines, including aviation/navigational and environmental requirements where available and to diminish the presence of ancillary structures on the site by minimizing site infrastructure, by burying collector system power lines avoiding stockpiling of excavated material or construction debris and removing inoperative turbines.

Implementation of erosion measures and re-vegetate cleared land with local seed stock of native species is also included.

5.3 *Noise*

5.3.1 *Construction Noise*

General EHS Guidelines give appropriate guidance on acceptable levels concerning onshore construction noise that should be decreased to protect locals. Impact assessments regarding underwater noise and vibration from offshore construction should be also conducted if there is a potential to impact marine life seriously and to identify suitable mitigation measures.

Wind turbines produce noise through a number of different mechanisms that can be approximately grouped into mechanical sources which are radiated by the surface of the turbine and by opening in the nacelle housing, and aerodynamic sources through a variety of processes as air passes over and past the blades.

5.3.2 *Operational Noise*

Wind turbines generate noise through many and various mechanisms that can be categorized into mechanical and aerodynamic sources. Gearbox, generator and yaw motors that produce their own characteristic sounds, while, in turn, fans and hydraulic motors can also add to acoustic emissions. On the other hand, the interaction of air and the turbine blades creates aerodynamic noise.

Noise impact should be evaluated according to the following principles: Receptors should be chosen based on their environmental sensitivity. Preliminary modeling can be as simple as assuming hemispherical propagation. It should also be focus on sensitive receptors within 2,000 meters of any of the turbines in a wind energy facility.

A preliminary modeling is possible to be adequate to assess noise impact only if turbine noise at all sensitive receptors are below anLA90of 35 decibels (dB) at a wind speed of 10 meters per second (m/s) at 10 m height during day and night times. In case it is not adequate to evaluate noise impact, more detailed modeling should be carried out including probably ambient noise measurements. All modeling should take into consideration the potential to rise noise levels if need be.

If noise criteria relied on surrounding noise is to be used, it is required to measure the background noise in the absence of any wind turbines. This ought to be done at one or more noise-sensitive receptors. Measurements at 10 m height over a series of 10-minute intervals should be taken as far as the background noise. At least five of theses 10-minute measurements should be taken for each integer wind speed from cut-in speed to 12m/s.

5.3.3 *Noise Mitigation Measures*

Nowadays, by using contemporary turbines mechanical noise is usually importantly lower in comparison with aerodynamic noise due to continuous improvement in airfoil design. Any additional recommended noise management measures possibly include to operate turbines in decreased noise mode and build walls or suitable noise barriers around possibly affected buildings and to restrict turbine operations above the wind speed in case turbine noise becomes unwelcome in the project-exact circumstances.

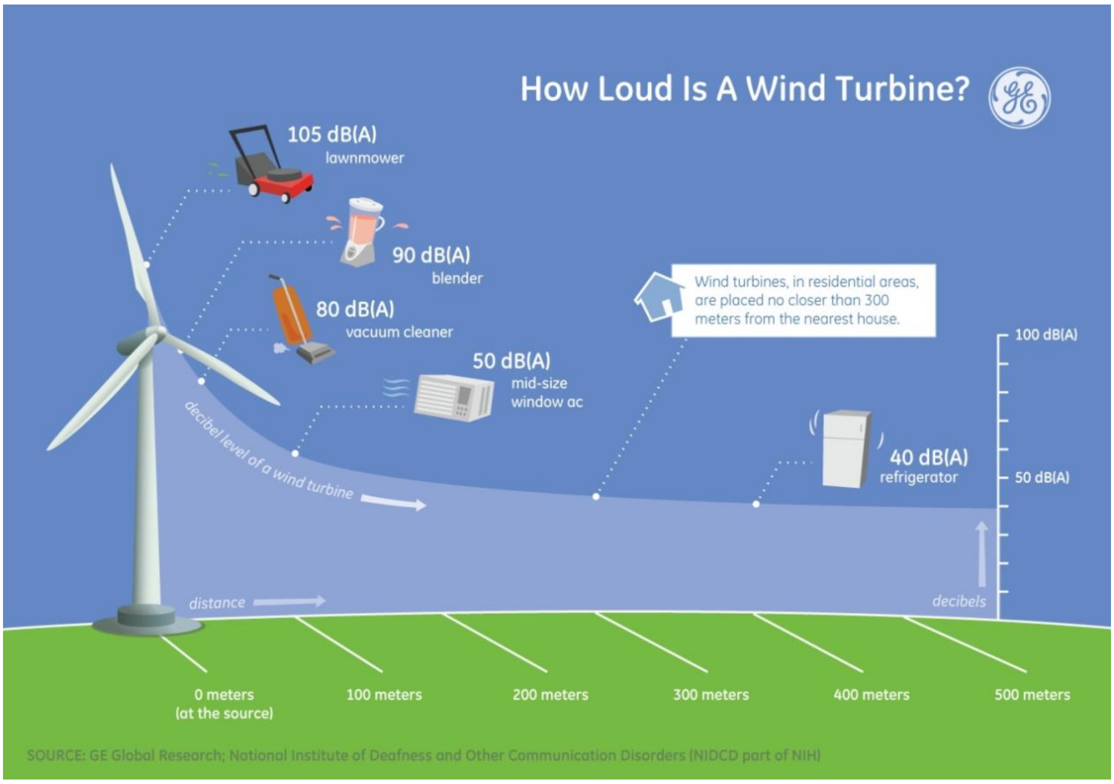


Figure 5: How loud is a Wind Turbine (GEReports)

5.4 *Biodiversity*

Adverse impacts on both onshore and offshore biodiversity throughout construction, operation, maintenance and decommissioning are a big possibility for wind power facilities. Examples of impacts contain bird and bat collision-related fatalities, displacement of wildlife, habitat conversion/degradation and noise to marine mammals as regards offshore facilities. In offshore environments, new structures and benthic disturbance could influence existing habitats or attract new habitat-forming species.

These impacts can be resulted from associated infrastructure, overhead transmission lines, meteorological masts, boat-based maintenance traffic, substations, underwater cables, lighting, boat-based maintenance traffic and roads.

To avoid adverse impacts on biodiversity sites of local, regional and international significance should contain national and international protected areas (including marine), Important Bird Areas (IBA), Key Biodiversity Areas (KBAs), Alliance for Zero Extinction (AZE) sites, Ramsar sites (Wetlands of International Importance), known congregatory sites and unique or threatened ecosystems. These sites could be significant migration routes, wetlands, staging, foraging or breeding areas, house bat hibernation areas and roosts just include significant topographical features.

With regard to offshore facilities, siting would contain a review of places of importance to the life history of marine life, especially fish, marine mammals, sea turtles or other habitats, such as mussel/oyster beds, reefs, sea grass, kelp beds and productive fishing areas. Consultation with related national and/or international conservation organizations should also be included.

5.5 *Pre-construction assessments*

Suitable site-specific baseline biodiversity information is possible to be needed to inform the Environmental and Social Impact Assessment (ESIA) depending on the stage of project development and the existing biodiversity value of the district. Baseline biodiversity surveys and seasonality should also be taken into consideration. Where in-country guidelines are still not well-developed, international guidelines should consider the need for surveys to be site-, species- and season-specific.

Surveys should take into account Site-specific issues such as geographical location, topography, consideration of habitats and proximity of the wind energy facility to sites of high biodiversity value. Moreover, Species-specific issues should be aimed at referring to species of flora and fauna of high biodiversity value, of a special international or national conservation status, endemic species and those which are at elevated risk of impact from wind power facilities. For example, species with a high collision risk contain certain soaring, aerial-displaying, and/or migratory birds and flocking birds and birds of prey; tree-roosting and insectivorous bats; species that deal with a high risk or visual disturbance include open-country species or may be attracted to wind energy facilities as perches or feeding areas; species that face a risk of collision with associated transmission lines, be at risk of electrocution or face a relatively high risk of disturbance from underwater noise. Depended on the impacts and potential mitigation choices they should probably be assessed on a species - by-species basis.

Season-specific issues get involved with surveys that should be taken into great consideration specific periods throughout the year when the project site may have a more significant ecological function or value. Surveys should be conducted when in-danger wildlife is identified, in areas with unusual aggregations of at-risk migratory birds and where existing biodiversity data are limited. This would be defined on a project-by-project basis.

To diminish collision risks to birds and bats, surveys should be carefully designed to sufficiently guide the micro-siting of turbines in combination with consideration of the locations of certain topographic, ecological or other landscape characteristics they may attract or concentrate the activity of flying wildlife in the project region.

Particular data-gathering methods and study designs should be guided by technical experts and selected based on sit- and species-specific considerations including vantage point surveys and other techniques to understand movement patterns, as appropriate.

The usage of radar can be much effective among other remote-sensing technologies in pre-construction studies that should be assessed on a project-by-project basis. Remote-sensing technologies are mainly important at offshore wind facilities.

Surveys for bats could also contain an evaluation of feeding and/or roosting habitats both within the project area and nearby, hand-held ultrasound bat detectors and deployment of static ultrasound detectors(especially at turbine locations).

Collision Risk Modeling (CRM) should be also necessary when wind energy facilities, specifically the offshore wind farm facilities, are established close to areas of high biodiversity value. Furthermore, where multiple wind farm facilities are established in the same geographical area and near places of high biodiversity value, a coordinated approach to surveys and monitoring should be implemented by wind project developers through cumulative impact assessments as data collection methods and the level of effort could be standardized.

5.6 *Mitigation*

5.6.1 *Mitigation Measures (Onshore)*

Adverse impacts on biodiversity can be reduced due to cautious site selection and layout. Moreover, a change in the number and size of turbines and their layout according to site-, species- and season-specific risks and impacts could be necessary in order to decrease the collision risk for most birds and vegetation clearing for construction. As for the location of associated infrastructure, biodiversity risk and impact assessments should be taken into great account, as well. Furthermore, if the wind power facility is set up near districts of high biodiversity value, active turbine management such as curtailment and shut-down on-demand procedures should be examined as part of the mitigation strategy that should be adapted and guided by a well-developed post-construction monitoring program. Technology led turbine shut-down should be considered only in certain cases. Artificially creating features in the environment, such as water bodies, perching or nesting areas, or even novel feeding places should be avoided as they draw the attention of birds and bats to the wind power facility. The same applies to predictable food sources, such as on-site or off-site waste disposal or landfills that can become approachable by vultures of the carrion-eating birds.

In addition, adjustments of cut-in wind speeds should be seriously considered to avoid potential bat collisions; in this way, a slight increase in cut-in wind speed may lead to important reductions in bat fatalities with minimal decrease in generation or financial returns. In the same context, the elimination of "free-wheeling"(free spinning of rotors under low wind conditions when turbines are not producing power) and avoidance of artificial light sources, where it is possible, and the usage of white blinking or pulsing lights can help significantly.

Bury on-site transmission lines, installment bird flight diverters on transmission lines and guy wires from meteorological masts and the usage also of 'raptor safe' designs for power line poles to decrease electrocution danger are also important ways to decrease bird collision in areas of high biodiversity value, too.

5.6.2 *Mitigation Measure (Offshore)*

Biodiversity-related and noise-related mitigation measures for offshore facilities may also include plan construction activities to avoid sensitive times of the year (e.g., migration and breeding seasons) and to coincide with less productive times of year for fish. Pile-driving activities, such as the usage of bubble curtains, are also recommended to assist preventing exposure of marine life to destructive underwater noise and vibration levels.

To lessen conventional pile-driving disturbance, auger piling or other means of fixing wind turbine generators are suggested. In case of seabed disturbance, monopole turbine foundation in shallower water and acoustic deterrent devices are also recommended.

In addition, there are acoustic deterrent devices emit sound to discourage marine life from the region throughout construction activities. If marine mammals or sea turtles are expected in the area, construction should be set up around 500 meters away. Hydraulic jet plowing technology, suitable choice of cable types, separation and burial depths for the cables are also included in less environmentally damaging technologies based on mitigation measures to provide safety where electrically or magnetically sensitive species are present.

5.7 *Shadow Flicker*

The phenomenon of shadow flicker occurs when the sun passes behind the wind turbine and casts a shadow. It might become a problem in case sensitive receptors (e.g., residential properties, workplaces, learning and/or health care spaces/facilities) are established nearby or have a specific orientation to the wind power facility.

Typically, shadow flicker is not an important issue to be solved for offshore wind energy facilities based on the distances between wind turbines and potential receptors onshore. Potential shadow flicker issues are possibly to be more significant in higher latitudes where the sun is lower in the sky and, as a consequence, casts longer shadows will be experienced.

In the event of nearby receptors, commercially available software can be used to model shadow flicker. Furthermore, it could be also used to foresee the duration and timing of shadow flicker occurrence under real weather conditions. If it is not possible to localize the wind power facility/turbines, it is also recommended that the predicted duration of shadow flicker effects experienced at a sensitive receptor not go beyond 30 hours per year and 30 minutes per day based on a worst-case scenario.

For the reasons above, prevention and control measures include the following: site wind turbines should appropriately avoid shadow flicker being experienced or conform to the limits referred to the duration shadow flicker occurrence. If shadow flicker limits are exceeded, wind turbines can be programmed to cease the operation. If wind turbines are painted with a matt, non-reflective finish, blade or tower glint is not considered to be an important matter anymore, especially for the communities.

Figure 6: A Schematic of Shadow Flickering (Buren Van Lag Weit)

5.8 *Water Quality*

5.8.1 Onshore

Measures to prevent and control issues such as the installation of turbine fundamentals, underground cables, access roads, and other supplemental infrastructure may lead to increased erosion, soil compaction, increased run-off and sedimentation of surface waters, are analyzed in the **General EHS Guidelines** and in the **Toll Roads EHS Guideline**.

5.8.2 Offshore

Because of the turbine foundations and subsurface cables, the marine seabed may be disturbed and an increase of suspended sediments in the water column can exist temporarily, thereby decreasing water quality, influencing marine species and commercial or recreational fisheries, is possible to take place. Appropriate guidance is provided in the **Ports, Harbors, and Terminal EHS Guideline** for the issue above and also for potential localized seabed erosion due to changes in water movements.

Among other prevention and control measures to deal with the impacts on water quality, carrying out a site selection process that examines the possible interference of the project's structural components with commercial or recreational fisheries and marine species habitats along with a plan for construction, installation and removal of structural components with respect to sensitive lifecycle periods are also important. In addition, control the use of jetting, bubble curtains and sediment traps are also included, too.

6. Useful Physics of Wind Technology

6.1 *Where does Wind Energy come from?*

All renewable energy (apart from tidal and geothermal power), even the energy in fossil fuels originates from the sun. The sun radiates 174,423,000,000,000 kilowatt hours of energy to the earth per hour; to put it differently, the earth receives 1.74 x 10^{17} watts of power. About 1 to 2 per cent of the energy that comes from the sun is converted into wind energy, which means around 50- 100 times more than the energy converted into biomass by all plants on planet earth.

6.2 *Temperature Differences Drive Air Circulation*

Generally speaking, the regions around equator at 0^0 latitude are heated much more by the sun in comparison with the rest of the globe. Hot air is lighter than cold air and will rise into the sky until it reaches roughly 10 km (6 miles) altitude and will spread to the North and the South. If the globe did not rotate, in this case the air would simply arrive at the North Pole and the South Pole, sink down and go back to the equator.

According to Danish Wind Industry Association the power emission from the sun is 1.37 kW m^2 on the surface of the sphere – there is the sun in its centre and the average radius of the earth trajectory. While the power hitting a circular disc with an area of 1.27 x 10^{14} $m^{2\cdot}$, the power that is emitted to the earth is thus 1.74 x 10^{17} W". On average, we should mention that plant net primary production is about 4.95 x 10^6 calories per square meter per year.

Danish Wind Industry Association also states that global net primary production (NPP) is actually the amount of energy available to all later links in the food/energy chain. The earth's surface area is 5.09 x $10^{14}m^2$ - the net power output that is stored by plants in therefore 1.91 x 10^{13} W or 0.011 % of the power that is actually emitted to earth.

6.3 *The Coriolis Force*

As the globe is rotating any movement on the Northern hemisphere is rerouted to the right if we take a look at it from our position on the ground. Concerning the southern hemisphere it is bent to the left. This obvious bending force is known as the Coriolis force because of taking its name from the French mathematician Gustave Gaspard Coriolis.

The phenomenon of The Coriolis force is clearly visible. For instance, railroad tracks are destroyed much faster on one side than the other. Furthermore, river beds are dug deeper on one side compared to the other. In the Northern hemisphere the wind has the tendency to rotate in counterclockwise direction as it moves closer to a low pressure area. On the other hand, in the Southern hemisphere the wind rotates in clockwise direction around low pressure regions.

6.4 *The Energy in the Wind: Air Density and Rotor Area*

Converting the force of the wind into a torque (turning force) a wind turbine can acquire its power input. The density of the air, the rotor area and the wind speed are the factors that define the amount of energy that the wind transfers to the rotor. For instance, a cylindrical slice of air 1 meter thick has the ability to move through the 2,300 m^2 rotor of a typical 1,000 kilowatt wind turbine. In case of a 54 meter rotor diameter each cylinder weighs 2.8 tones.

6.5 *Density of Air*

As a rule, the kinetic energy of a moving body is proportional to its mass (or weight). Moreover, the kinetic energy in the wind relies on the density of the air that is its mass per unit of volume. To put it differently, the heavier the air, the more energy is received by the turbine. At normal atmospheric pressure and at 15^0 Celsius air its weight is around 1.225 kilograms per cubic meter, but the density decreases slightly when humidity increases. Furthermore, the air is denser when it is cold compared to when it is warm. At high altitudes, (in mountains) the air pressure is lower and as a result the air is less dense.

6.6 *Rotor Area*

A normal 1,000 kW wind turbine has a rotor diameter of 54 meters that is a rotor region of some 2,300 square meters. The rotor area defines how much energy a wind turbine is able to gather from the wind. In addition, as the rotor area rises with the square of the rotor diameter, a turbine which is twice as large will take $2^2 = 2 \times 2=$ four times as much energy.

6.7 *Wind Turbines Deflect the Wind*

As a wind turbine will avoid the wind before the wind reaches the rotor plane, we will never be able to catch and hold all of the kinetic energy in the wind by using a wind turbine.

6.8 *The Stream Tube*

The wind turbine rotor captures the kinetic energy of the wind which has already slowed it down and converts it into rotational energy. The wind will be moving more slowly in this way to the left of the rotor than to the right of the rotor. The air will have to occupy a larger cross section (diameter) behind the rotor plane as the amount of air entering via the swept rotor area from the right (every second) must be the same as the amount of air leaving the rotor area to the left.

The stream tube (a name for an imaginary tube around the wind turbine rotor illustrated to help us in graphs) displays exactly how the phenomenon works. At this point it should be mentioned that the wind is not going to slow down to its final speed immediately behind the rotor plane – the slowdown will take place when the speed becomes almost constant.

The Air Pressure Distribution in front of and behind the rotor is also illustrated in many scientific graphs proving that as the wind approaches the rotor from the right the air pressure rises slowly since the rotor plays the role of a barrier to the wind.

6.9 *What Happens Farther Downstream?*

If we take the decision to move farther downstream the turbulence in the wind will bring about the slow wind behind the rotor to blend with the quicker wind from the surrounding area. The wind shade behind the rotor as a consequence will slowly lessen as we move away from the turbine.

6.10 Why not a Cylindrical Stream Tube?

We cannot adopt the case of a Cylindrical Stream Tube. Even if it sounds right for a turbine rotor to be capable to turn if it was placed in a large glass tube, the result will be disappointing. We do know that the wind to the left of the rotor moves with a lower speed compared to the wind to the right of the rotor. But the volume of air that enters the tube from the right each second have to be the same as the volume of air that leaves the tube to the left. As a conclusion, in case we have some obstacle to the wind (our rotor) within the tube, some of the air that comes from the right has to be deflected from entering the tube because of the high air pressure that is created in the right end of the tube. For this reason, the cylindrical tube cannot give an exact picture of what occurs to the wind when it meets a wind turbine.

6.11 *Wind Speed Measurement: Anemometers*

The measurement of wind speeds is commonly done by using a cup anemometer that has a vertical axis and three cups with a view to capture the wind. The number of revolutions per minute is registered electronically as it fitted with a wind vane to detect the wind direction. Instead of cups, anemometers can be occasionally fitted with propellers. Other anemometer types contain ultrasonic or laser anemometers that find the phase shifting of sound or light that can be revealed from the air molecules. Hot wire anemometers detect the wind speed via minute temperature differences that occur between wires that are placed in the wind and in the wind shade. Non-mechanical anemometers are less sensitive to icing but cup anemometers even if they have the tendency to be used everywhere there are special models with electrically heated shafts and cups that can be used in arctic areas.

6.12 *Quality Anemometers are a Necessity for Wind Energy Measurement*

If there are plans for building a wind farm, it may be an economic disaster in case cheap anemometers are bought as they could be inaccurate and calibrated poorly due to the fact that measurement errors can be appeared at least 5% or even 10%. As a result, risk counting on an energy content of the wind that is 1.1^3 - 1= 33% higher comparing with what happens in reality. If there is a need to re-estimate your measurements to a different wind turbine hub height (say, from 10 to 50 m height), you may even multiply that error with a factor of 1.3 therefore it is possible to end up with a 75% error on energy calculations.

On the other hand, it is probable to buy a professional, well calibrated anemometer with a measurement error about 1% for around 700-900 USD in an attempt to reduce the risk of catastrophic economic error. In this case, well reputed wind energy research institutions can usually give valuable advice on purchasing anemometers.

6.13 *Wind Speed Measurement in Practice*

Fitting an anemometer to the top of a mast that has got the same height with the expected hub height of the wind turbine to be used is in fact the best way regarding measuring wind speeds at a wind turbine site. In this way, the disturbances of airflows from the mast itself become very small. It is strictly necessary for anemometers placed on the side of the mast to be set up in the prevailing wind direction to lessen the wind shade from the tower as much as possible.

6.14 *Which Tower?*

Thin cylindrical poles are commonly more preferable over lattice towers for fitting wind measurement devices to reduce the wind shade that comes from the tower.

The poles come as kits that are easily assembled and installed on a mast for wind measurements without a crane. Anemometer, pole and data logger will often cost about 5,000 USD.

6.15 *Data Logging*

A data logger is really small computer battery operated on electronic chips wind speeds and wind directions data that originate from the anemometer(s). Every month there is a need for going to the logger to collect the chips and replace them with blank chips to gather the next month's data.

6.16 *Arctic Conditions*

A heated anemometer is absolutely necessary in case of freezing rain in the region or frost from clouds in mountains. This sort of anemometer requires an electrical grid connection in order to run the heater.

6.17 *10 Minute Averages*

Wind speeds are commonly measured as 10 minute averages to become compatible with most standard software. In case of using various periods for averaging the result for wind speeds are different.

6.18 *The Wind Rose*

Strong winds commonly originate from a specific direction. The distributions of wind speeds and the frequency of the different wind directions can be used to illustrate a so-called wind rose (as an example) to better understand meteorological observations as for wind speeds and wind directions. All this data is collected in terms of frequency, mean wind speed and mean cube of wind speed has been multiplied by a number that guarantees that the largest wedge in the set precisely matches the radius of the outermost circle in the illustration that could be created to depict the above data.

6.19 *Wind Roses Vary*

Wind roses are a form of meteorological fingerprint and change from place to place. When wind roses come from neighboring areas it is practically safer to take an average of the wind roses from surrounding observations, in cases for instance, of complicating terrain where mountains and valleys running in completely different directions. The wind rose will give information as for the relative distribution of wind directions and not the real level of the mean wind speed.

6.20 *How to Use the Wind Rose*

When siting wind turbines, a look at the wind rose is obviously very significant. If a large share of the energy in the wind has a particular direction, we would like to have only few obstacles to be arisen, keeping in mind that a terrain as smooth as possible in the direction of the wind turbines which will be placed in the landscape, is always of great consideration.

The wind patterns might change from year to year and for that reason the energy content could vary (commonly by some ten percent), therefore, it is essential to have observations from several years to make a trustworthy average. Planners of large wind parks will be depended on one year of local measurements and then use long-term meteorological observations from near weather stations to make any necessary adjustments are possible to get a reliable long term average.

The wind rose has as its source the credible European Wind Atlas which includes a description of each of the measurement stations, so we might be warned regarding any possible local disturbances to the airflow.

7. Occupational Health and Safety

Occupational health and safety hazards throughout the construction, operation and decommissioning of onshore and offshore wind energy facilities are usually similar ro those of most large industrial facilities and infrastructure projects. Along with prevention and control of other physical, chemical, biological and radiological hazards are also discussed in the **General EHS Guidelines**.

Among other things, special importance is given to working at Height, over Water or in Remote Locations and Lifting Operations, as well.

7.1 *Working at Height and Protection from Falling Objects*

Working at height occurs very often during all phases of operation at any wind power facility but is mainly relevant for maintenance reasons. Above all, the prevention of a fall should be the main consideration. Among other dangers, falling objects and bad weather conditions, like wind speed, extreme temperatures, humidity and wetness need to be seriously considered; suitable planning and the allocation of sufficient resources are obviously required.

Preferred mitigation methods may include elimination or reduction of work at height during the planning and design phases of an installation, if it is practicable. Assembling structures and carrying out supplemental works at ground level and after that lifting the complete structure into position can become an excellent example to be followed whether it is feasible and cost effective. Appropriate work equipment, collective protection systems, such as edge protection or guardrails, safety nets and airbags can also be used to diminish any possible consequences of a fall.

To prevent working-at-height and falling-object incidents it is absolutely necessary to ensure that all structures are designed and built to the suitable standards. Moreover, not only suitable exclusion zones should be existed and maintained underneath any working-at-height activities, but also employees should be provided with an appropriate work-positioning device ensuring the connectors on positioning systems are compatible with the tower components to which they are connected.

All employees should also become well-trained and capable enough in the use of all working-at-height and rescue systems in place. Hoisting equipment should also be rated and maintained, too. All tools and equipment are ought to be fitted with a lanyard or capture netting if it is practicable. An approved tool bag should also be used for raising or lowering tools or useful materials to workers on elevated structures.

Signs and other obstructions should be removed from poles or structures during work, while in case of lightning strikes or poor weather conditions conducting tower installation or maintenance work should be avoided. Finally, an emergency rescue plan should be available in any case of need, especially if operatives become stranded or incapacitated while at height.

7.2 *Working over Water*

Prevention and control measures related to working over open water contain the basic principles as they have already been described for working at height, as above, additionally to the following: Complete a risk assessment to develop a safe system of work for all working-over-water tasks and allocate suitable resources to reduce the hazards. To make sure all operatives are well-trained and capable enough concerning all tasks they have undertaken, including usage of all equipment and operate Personal Protective Equipment (PPE).

Approved buoyancy equipment (e.g., life jackets, vests, floating lines, ring buoys) when workers are over or adjacent to water where there is a drowning risk is also used along with survival suits that should be put into effect when there is a drowning danger. In case of exposure to low water temperatures which can end up to hypothermia, control measures such as survival suits must be implemented. Furthermore, working-at-height fall-arrest equipment should be compatible to buoyancy equipment in order to be used in cases of need. Workers should be trained to avoid salt spray and contact with waves. In addition, suitable rescue vessels with qualified operators and emergency staff in case of need.

7.3 *Working in Remote Locations*

Remote working especially in offshore sites is extremely demanding and risky; planning is absolutely necessary to ensure the safety, health and welfare of employees. Suitability of communication equipment, the necessary safety equipment in the location and the training and capability of staff should also be ensured. Among others, supervision by competent personnel authorized to take seriously decisions at the work location, means for managers to be in the position to track the working crew, the existence of a local emergency plan and the certain presence of qualified first-aid-trained personnel for the safety of the work crew are of major importance, as well. Information on Lone and Isolated workers can be found in the **General EHS Guidelines.**

7.4 *Lifting Operations*

Lifting operations constitute an integral component of the construction of any wind energy facility. Components are typically assembled to the site where assembly will take place. This includes using large, complicated pieces of lifting equipment to raise loads of varying dimensions and weighs lots of times. Even if the lifting requirements during the construction of an onshore wind facility are similar to any other construction project, when we refer to offshore environment the lifts become a very complicated operation that also contains multiple vessels and cranes; as a result, numerous hazards can be created. Among others, sea states can influence the stability of lifting platforms, a marine environment can speed up the degradation of lifting point on components and communication problems should be dealt with between multinational crews on separate vessels while carrying out the lift.

The appropriate management of lifting operations needs the good usage of capable staff, careful planning, efficient communication and a high level of supervision during carrying out a lift. Special consideration is ought to be given to all relevant information that should be known about the load (e.g., the size, weight, method of slinging and attachment points) and to the lifting equipment and its condition especially if it is suitable and in good condition, capable of supporting the load and recipient of any legal inspections required.

Furthermore, extra care should be taken to ensure all supervisors, equipment operators and slingers are trained and capable enough regarding lifting equipment and intended lifting techniques. Exclusion zones must be set up and appropriately maintained to avoid any unauthorized access to lifting areas. In case of lifting large loads, much consideration should be taken to weather conditions and if they are favorable for the task.

Any supplementary information concerning severe weather can be found in the **General EHS Guidelines**. A planning meeting among all the parties that are involved in the lift is also recommended in order to define the details of the lift the roles of each party and the methods used to effectively communicate.

7.5 *Community Health and Safety*

Most of the large industrial facilities and infrastructure projects share similar community health and safety hazards throughout the construction, operation and decommissioning of onshore and offshore wind energy facilities. These dangers may be relevant to the structural safety of project infrastructure, life and fire safety, public accessibility and emergency situations, as well. Their management is discussed in the **General EHS Guidelines**. Blade and Ice Throw, Aviation, Marine Navigation and Safety, Electromagnetic Interference and Radiation, Public Access and Abnormal Load Transportation are also included to the abovementioned community health and safety hazards specific to wind energy facilities.

7.6 *Blade/Ice Throw*

Public safety might be affected by a failure of the rotor blade or part thereof but the general risk of blade throw is very low. Turbines must be also set located at an acceptable distance **(setback)** between wind turbines and close sensitive receptors in order to maintain public safety in case of ice throw or blade failure. Additionally, blade throw risk management strategies contain establishing setback distances between turbines and populated locations. The minimum setback distance is 1.5 x turbine height (tower + rotor radius) although modeling suggests that the theoretical blade throw distance can vary with the size, shape weight and speed of the blades and the height of the turbine. The minimum setback distances which are needed to meet noise and shadow flicker limits should be maintained in relation to sensitive residential receptors to provide more protection. Therefore, selecting wind turbines that have been subject to independent design verification/certification (e.g., IEC 61400-1) and surveillance of manufacturing quality is as significant as lightning protection systems are appropriately installed and maintained. Conduct regular blade inspections and repair any defects if need be. Vibration sensors should also be established regarding any imbalance in the rotor blades with a view to shutting down the turbine if it is necessary.

Ice throw risk-management strategies should pay attention to setback distance but also to restrict wind turbine operations due to weather conditions that can lead to ice accretion. The same applies to ice detectors that should shut down the turbine to an idling state in case of ice. There should also be post warning signs at least one rotor diameter from the wind turbine if turbines are necessary to operate in icing conditions and in a remote area.

Turbines with ice detectors to control blade-heating systems that are designed to throw ice away from the blade surface, may need cautious efficiency turbine maintaining as the productiveness of heating systems can also be affected. Post warning signs should be put at entrance points to the wind energy facilities and working procedures should include precautions before maintenance staff have access to the site in icing conditions. It is also essential turbines be of suitable specification to achieve reliable and long-lasting operation.

7.7*Aviation*

7.7.1 *Aircraft Safety*

Nowadays, wind turbine blade tips can reach up to 200 meters at their highest point and if they are established near airports, known flight paths or military low-flying areas, aircraft safety may be seriously affected. For this reason, it is of crucial importance to consult with the relevant aviation authorities before installation and when it is feasible, siting wind energy facilities ought to be avoided.

When wind energy facilities are set up close to radar, the operation of aviation may be affected by signal distortion due to the physical structures of the tower/turbine and the rotating blades. To address these impacts, Prevention and control measures include consideration of wind energy design options, including geometric layout, location of turbines and changes to air traffic routes. Consideration of radar design alterations and consultation should also be undertaken with the relevant aviation authorities to define prevention and control measures.

7.8 *Marine Navigation and Safety*

7.8.1 Marine Safety

If there are any ports or known shipping lanes, an offshore wind turbine may impact shipping safety through collision or change of vessel traffic. This may lead to damage to turbines and/or vessels as well as pollution risk connected to collisions. Offshore turbines, cable routes and other associated infrastructure demand cautious consideration in relation to siting to take into account factors like anchorage areas, seabed conditions or archaeology sites to reduce impacts where it is possible. Offshore wind turbine generators can meddle in radar operation used for shipping navigation and as a result there is the potential to impact normal and shipping operations.

Prevention and control measures include consultation with marine regulatory traffic authorities before installation and if it is practicable to avoid siting wind energy facilities near ports and within known shipping lanes. The usage of anti-collision lightning and marking systems on turbines as well as the use of guard vessels should also be taken into great consideration. To minimize disruption to other sea users, safety zones can be set up around each turbine and construction vessel throughout the construction phase. The usage of reference floating markers to aid navigation is significant, too.

Figure 7: Vessels and Offshore Wind Plant (Palfinger Marine)

7.9 *Electromagnetic Interference*

Wind turbines could possibly cause electromagnetic interference with telecommunication systems (e.g., microwave, television or radio) and is caused by path obstruction, shadowing, reflection, scattering or re-radiation. The location of the wind turbine relative to the transmitter and receiver, characteristics of the rotor blades, signal frequency receiver traits and radio wave propagation characteristics in the local atmosphere are the main factors of this interference.

7.10 *Telecommunication Systems*

Impacts on telecommunications systems can also include broadcast-type systems and on point-to-point systems. Prevention and control measure to address such kind of impacts include modification of the position of wind turbines in order to avoid direct physical interference of point-to-point communication systems. Consultation with relevant operators and application of buffers can minimize impacts. Installation of a directional antenna, change of the existing aerial and installation of an amplifier to boost the signal are also recommended.

7.11 *Television*

To deal with the impacts to television broadcast Prevention and control measures include siting the turbine away from the line-f-sight of the broadcaster transmitter. Installation of higher-quality or directional antenna if interference is detected throughout operation is also important. If it is necessary, the antenna should be directed toward an alternative broadcast transmitter. Installation of digital television or an amplifier and relocation of the antenna are also recommended.

7.12 *Public Access*

It is possible safety issues may be arisen concerning public access to wind turbines. For that reason, any public rights of way located within and close to the wind energy facility should be identified prior to construction. Prevention and control measures include the usage of gates on access roads and where public access is not promoted to the site and/or no current rights of way across the site, public access to the turbines should be obviously prohibited.

Fencing of a suitable standard around the substation with anti-climb paint and warning signs should be also provided along with prevention of access to turbine tower ladders. In addition, post information boards regarding public safety hazards and emergency contact information should be provided, as well.

7.13 *Abnormal Load Transportation*

Traffic and transportation issues concerning siting wind energy facilities are largely covered within **the General EHS Guidelines** and the **Toll Roads EHS Guideline**. The main challenge includes the transportation of oversized or heavy wind turbine components (blades, turbine tower sections, nacelle and transformers) and cranes to the site. Impacts on existing offsite roadways, bridges crossings over culverts, overpasses/underpasses, turning radii and utilities as well as the possibility of requiring surface replacements, upgrades or resettlements should be evaluated by the logistics, traffic and transportation studies. Schedule deliveries outside of peak hours, provision or traffic management and police escorts where required should be also seriously considered.

7.14 *Grid Connection*

Large wind turbines have to be connected to the electrical grid and simultaneously it is strictly necessary for smaller projects to be reasonably close to a 10-30 kilovolt power line if the cost is not extremely high. The generators in large, contemporary wind turbines generate electricity at 690 volts. A transformer set up close to the turbine or inside the turbine tower has the capability to convert the electricity to high voltage (typically 10-30 kilovolts).The electrical grid close to the wind turbine(s) would receive the electricity that comes from the turbine. The grid may need **special reinforcement** in case there are many turbines connected to grid.The **feasibility of building foundations** of the turbines and the road construction to reach the site using heavy trucks must be taken under great consideration to ensure the success of the wind turbine project.

7.15 Pitfalls in Using Meteorology Data

Meteorologists gather wind data for weather forecasts and aviation all this data is used to estimate the general wind conditions for wind energy in a region. Wind energy planning is pretty important for weather forecasting.

Wind speeds are heavily affected by the surface roughness of the surrounding area, of trees, lighthouses or other buildings and the contours of the local terrain.For the reasons above, it is absolutely necessary to estimate wind conditions by making precise calculations that compensate for the local conditions under which the meteorology measurements are made. In most cases using meteorology information directly there is the risk of underestimating the true wind energy potential in a specific area.

8. Wind Turbines: Horizontal or Vertical Axis Machines?

8.1 *Horizontal Axis Wind Turbines*

Horizontal Axis Wind Turbines are grid-connected commercial wind turbines today just like propeller-type rotors. The aim of the rotor is to convert the linear motion of the wind into rotational energy that can be used to drive a generator. The same basic principle is also applicable to a contemporary water turbine where the flow of water is concurrent to the rotational axis of the turbine blades.

8.2*Vertical Axis Wind Turbines*

Classical water wheels allow the water to arrive at a right perpendicular angle to the rotational shaft of the water wheel.Vertical axis wind turbines (VAWTs) seem to be like water wheels. It is true that some vertical axis turbine types are capable of working with a horizontal axis; however, they could not beat the efficiency of a propeller type turbine.

The only vertical axis turbine which has ever been manufactured commercially at any volume is the Darrieus machine which took its name from the French engineer Georges Darrieus who obtained the patent of the design in 1931. This machine is featured by its C-shaped rotor blades which gave it the form of an eggbeater and it is typically built with two or three blades. Among the basic theoretical advantages of a vertical machine focus on the place of the components like the generator or gearbox which should be set up on the ground making unnecessary a tower for the machine. Additionally, a yaw machine is not needed in order to turn the rotor against the wind.

On the other hand, among the basic disadvantages are wind speeds which will be very low on the lower part of the rotor near the ground level. Furthermore, the overall efficiency of the vertical axis machines is not so much impressive. The machine is also not self-starting- the Darrieus machine needs a 'push' before is starts. The machine might also need guy wires to hold up but these sorts of wires are very impractical in heavily farmed regions. Last but not least, when replacing the main bearing for the rotor needs removing the rotor on both a horizontal and a vertical axis machine, which, in fact, means tearing the entire machine down.

8.3 *Upwind Machines*

Upwind machines have the rotor facing the wind and their main advantage is that the wind shade behind the tower is avoided. The big majority of wind turbines have got this design, as well.

Nevertheless, there is some kind of wind shade in front of the tower, thus each time the rotor passes the tower this power that comes from the wind turbine drops slightly.

The main disadvantage of upwind designs is that it is absolutely necessary for the rotor to be made inflexible enough and set up at some distance from the tower. Moreover, an upwind machine needs a yaw mechanism to keep the rotor facing the wind, too.

8.4 *Downwind Machines*

Downwind machines have the rotor set up on the lee side of tower. There is also a theoretical benefit they might be built without a yaw mechanism if the rotor and nacelle have an appropriate design that makes the nacelle follow the wind without resisting. As for large wind turbines, it is actually a dubious advantage but since cables are not necessary to lead the current away from the generator, it seems worth. It is difficult to untwist the cables when the machine has been yawing without resistance in the same direction for a long time. However, a more significant benefit is that the rotor might be made more flexible. This advantage has to do with both the weight and the structural dynamics of the machine. Additionally, a downwind machine can be build somewhat lighter than an upwind machine. But the fluctuation in the wind power because of the rotor passing via the wind shade of the tower can give more fatigue loads on the turbine compared to an upwind design.

9. Offshore Wind Conditions

9.1 *Wind Conditions at Sea*

The roughness of a seascape is very low at constant wind speed while the surfaces of seas and lakes are clearly very smooth. When increasing wind speeds some of the energy in the wind is used to build waves and once they have been build up the roughness reduces again. Therefore, we have got a surface with different roughness just in case of areas which are covered with more or less snow.

Speaking in general terms, the roughness of the water surface is very low and obstructs to the wind are few. It is necessary to account for islands, lighthouses etc.

when wind calculations are done similarly to upwind obstacles or alterations in roughness on land.

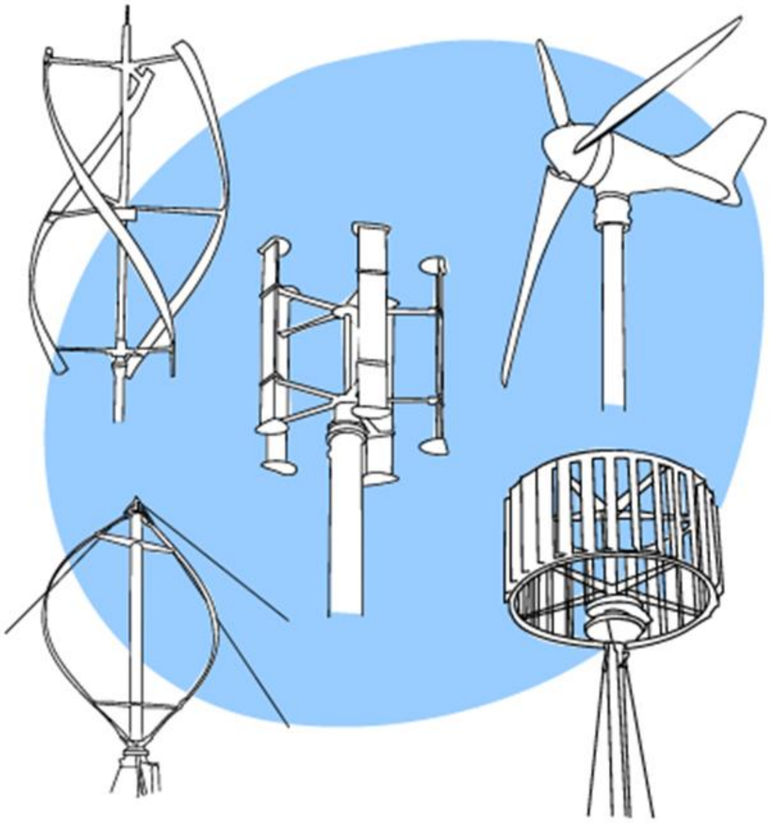


Figure 8: Illustrating the Wind Turbine Concepts (Siemens)

9.2 *Low Wind Shear Means Lower Hub Height*

Wind shear at sea is very low due to low roughness and as a result the wind speed does not change very much with alterations in the hub height of wind turbines. It might thus be most economic to use low towers of perhaps 0.75 times the rotor diameter for wind turbines set up at sea, relaying on local conditions. Towers on land sites are commonly about the size of the rotor diameter or taller.

9.3 *Low Turbulence Intensity = Longer Lifetime for Turbines*

The wind at sea is usually less turbulent compared to land. Wind turbines set up at sea might be expected to have a longer lifetime than land based turbines. The low turbulence at sea is mainly because temperature variations among various altitudes in the atmosphere above the sea are smaller than above land. Sunlight will get into several meters below the sea surface while on land the radiation that comes from the sun heats the uppermost layer of the soil which results in becoming much warmer.

As a consequence, the temperature difference between the surface and the air will become smaller above sea in comparison with that above land, which also explains the lower turbulences.

9.4 *Wind Shade Conditions at Sea*

In accordance with Risø National Laboratory, the conventional WAsP model regarding onshore wind modeling is still in the process of being modified for offshore wind conditions. The different productions outcomes obtained by the experience of the first major offshore wind park at Vindeby, Denmark, and the afterward built wind park at Tunø Knob, Denmark, has resulted in new investigations with anemometer masts been set up offshore in a number of locations in Danish waters since 1996. The preliminary outcomes display that wind shade effects that come from land might be more significant even at distances up to 20 kilometers in comparison with what was thought in advance. However, it appears that the offshore wind resource might be some 5 to 10 per cent higher compared to what was earlier assessed.

10.Analysis of the big players of the Industry

10.1*Vestas*

Vestas Wind System A/S is the largest global player and market leader in the wind turbine manufacturing industry headquartered in Copenhagen, Denmark. It has already delivered 66 GW (53,743 wind turbines) in 73 countries in the whole world and has been manufacturing facilities in North and Latin America, Europe and Asia. It should be mentioned that for full year 2014 Vestas' revenue amounted to EUR 6.9bn. Vestas Wind Systems A/S became listed on Copenhagen Stock Exchange. (Vestas 2015a). Vestas present strategy is called Profitable Growth for Vestas and introduced after the economic downturn in 2012. New strategy is concentrated on spending cuts and is set to three focus areas: Reduction of costs via operational excellence. Secondly, decrease in investments via asset-light solutions and simplified product roadmap. And last but not least improvements of capacity utilization and capital efficiency via divestments and supply third parties (Vestas 2013).

10.2 *Enercon*

Enercon has produced more than 22,000 wind turbines that have been established in more than 30 countries with a power generating capacity exceeding of 32.9GW.Enercon GmbH was founded in 1984 in Germany and its head office is in Aurich, Lower Saxony and has production facilities in Germany, Sweden, Brazil, Turkey, Portugal, Canada, Austria and France. Furthermore, it has more than 300 service stations worldwide. Relied on installed capacity, Enercon's market share in Germany is 43.1% compared to 10.1% worldwide and is concentrated only on onshore direct drive wind turbines. In 1993Enercon pioneered the gearless direct drive wind turbine technology-Enercon E-40- with a rated power of 500 kW. In according withEnercon, this innovative drive system with few rotating components protects almost friction-free energy flow and provides significantly increased performance and reliability. In addition, it decreases mechanical stress, operating and maintenance costs and increases system's service life. However, Enercon has already started to deplete the non-gearbox concept. All Enercon systems characterize a grid connection system that fulfills present grid connection requirements and can be easily integrated in any supply and distribution structure. It gives solutions to normal operation such as reactive power management, voltage controland critical situation coming from network short-circuits or bottlenecks (Enercon 2015a).Enercon offers three onshore wind turbine product lines. Sub MW ranging 800 – 900 KW, MW consisting 2-3 MW and Multi-MW consisting 7, 58 MW wind turbine model (Enercon 2015b).

As it has already mentioned before, Enercon is concentrated only on onshore and direct drive turbines. Additionally, the company does not offer its turbines on US nor Chinese markets. During an interview, Enercon'sCEO Hans-Dieter Kettwig stated: *"We have always tried to sell on the basis of quality. Enercon customers buy from us because of our quality. In the end, our maintenance service package – the Enercon Partner concept – and our technology still make us competitive at attractive prices for both us and our customers*" (Renewables International 2012). Kettwig indicates that the company focusses on technological and service concept excellence. For that reason, Enercon's strategy could be classified as a differentiation marketing strategy. As Enerconisonly concentrated on specific markets, the strategy could be also categorized as a focus type of generic strategy. Porter (1980) describes the focus type generic strategy as concentrating on a particular buyer group, product line or geographical market. The aim of focus strategy is to serve the narrow market effectively and drastically in comparison with competitors who are competing more broadly.

10.3 *Siemens Wind Power*

Siemens Wind Power A/Soperates as a subsidiary of Siemens Aktiengesellschaft and is based in Brande, Denmark. The company offers wind power solutions for onshore, offshore and coastal sites. It was established in 1980 and was formerly known as Bonus Energy A/S and changed its name to Siemens Wind Power A/S when taken over by Siemens AG in December 2004 (Bloomberg Research 2015b).

Siemens AG strategy focuses on company positioning all along the value chain of electrification, including power generation, power transmission, power distribution, smart grid, efficient application of electrical energy and interrelated fields, such as electrification, automation an digitization. Siemens representsthat key part of its strategy as the worldwide integrated go-to-market setup (Siemens 2015a) Siemens AG also includes Siemens Financial Services – a subsidiary offering business-to-business project and structured financing as well as leasing and equipment finance (Siemens 2015b).

Siemens describes its Wind Power and Renewables division's strategy as follows: *"The Wind Power and Renewables Division is a leading supplier of reliable, environmentally-friendly and cost-efficient renewable energy solutions. Driving down the cost of wind power is our key target as we strive to make renewable energy fully competitive with conventional energy sources''* (Siemens 2015d). The focus on lowering costs is also pointed out by Siemens Wind Power CTO Henrik Stiesdal (CleanTechnica 2013). Considering the focus on systematic modularization the Siemens Wind Power's strategy could be classified as a cost leadership type generic strategy.

11. Wind turbine manufacturing Industry's position in Industry's life cycle

Following the downturn in 2013, wind turbine industry has started to take over disciplines from automotive industry and hire executives from automotive in order to change focus to cost control. As market leader'sVestas Chairman of Board of Directors Bert Nordberg stated in company's annual report in 2014*"The strategic direction is in place, and we have a highly capable Executive Management team leading the way. We are in a strong position to drive the business forward and with that reduce the cost of energy and ensure an attractive return on investment for our shareholders."*(Vestas 2015c, pp 3).With that statement Nordberg expresses his belief that cost control is a top priority in Vestas's strategy in the coming years.Vestas and Gamesa have already made a usage of this approach. Vestas has also been searching ways to outsource or make joint ventures, like the one it has formed with Mitsubishi Heavy Industries for offshore wind turbines development (Backwell 2013).

The industry's growth and structure has stabilized (GWEC 2014). Therefore, it is in a transition process from growth phase to maturity phase.

11.1 *Core competences*

Product engineering and quality management are included in the core competences for the emerging company. Strong coordination, among other functions, on research and development, product development and marketing are of crucial importance to develop a good reputation as are liable wind turbines producer company. In addition, marketing should focus on technological advantages and reliability of the products. The production in fact, follows a horizontally integrated model. On-site assembly is used to mediate the market barrier that capital is augmented in large quantities as well as to make briefer the manufacturing process. Nevertheless, operational excellence is not a strategic trade but a mandatory part of a company.

Even if the industry is about to reach its maturity stage, the door is open to the wind turbine manufacturing industry. While the lion’s share of major wind turbine manufacturing companies draws the attention to offshore wind turbines development, the market of direct drive onshore wind turbines predominated by one company. Because onshore wind turbines still account for the vast majority of the market, creating a new experience curve to this segment is a strategy for newcomers to leapfrog the industry.

When entering that specific industry, one of the major barriers is the well established relationships between old wind turbine manufacturers and customers – utility companies. Due to the lack of sufficient references, new companies cannot become competitive at the tenders. Acquiring the references by forward integration sounds an appropriate strategy to overcome barriers. To enter the market, a wind turbine company should own its own wind park and have also made new product testing. As wind parks' product, electricity is a commodity and sold on a commodity market, the know-how needed to set up and operate a wind park does not require wind turbine manufacturer to acquire new knowledge. Furthermore, most of wind turbine manufacturers have the capacity to execute turnkey projects and operate wind parks. Due to this competitive situation, as having this capacity is a critical success factor in the wind turbine market, competition compels companies to have this know-how even without the need for forward integration strategy.

Further research on this field may include developing the market entrance strategy based on needs of concrete utility companies. The development should be conducted using bottom-up, repeated customer interaction oriented approach, such as Ries' (2011) Lean Startup. The expected result is set of recommendations on technology development and business model level.

12. Wind Energy Sources International Trends

People these days have come to realize that wind power 'is one of the most promising new energy sources' that can be in the service of humanity as an alternative to fossil fuel-generated electricity. And that is the ultimate goal. To build a future powered by clean, abundant and affordable renewable energy for the welfare and safety of the next generations.

Thanks largely to current technological advances, wind energy could supply 20% of America's electricity (or approximately the quantity nuclear power provides) with the usage of turbines which could be installed on less than 1% of its land area. Wind equipment, in turn, would occupy less than 5% of the land inside that region while the remaining 95% could keep on being used for activities such as farming or ranching. By the year of 2020, wind power may be supplied to 10 million average American homes, preventing in this way 100 million metric tons CO2 emissions per year. Reducing our reliance on fossil fuels is a major challenge and severely critical to the health of all living things, and wind energy can do just that.

America's wind machines annually produce the 3 billion kWh of electricity which, in fact, displace the energy equivalent of 6.4 million barrels of oil and avoid in that way not only 1.67 million tons of carbon emissions but also sulfur and nitrogen oxide emissions which, in truth, cause smog and acid rain. That is to say, 'more wind power means less smog, acid rain, and greenhouse gas emissions.'

Windmills may have been in existence for almost 1500 years, but it was not envisaged that wind power would become affordable enough to establish superiority over fossil fuels. Indeed it has. In reality, many utility services all over the world offer wind-generated electricity at a premium price of 2 to 3 cents per kWh. For instance, if a household made use of wind power for 25% of its needs, it would spend only $4 or $5 dollars every month for it and the price is still falling.

As a consequence, a comparison between the above and 4.8 to 5.5 cents per kWh for coal or 11.1 to 14.5 cents per kWh for the usage of nuclear power lead us to the conclusion that wind energy is cheaper than any other new electric generation apart from natural gas - which, in turn, emits one pound of greenhouse gases for each kWh of electricity it produces. The success of this energy is partly owing to the fact that its costs represent a decrease of more than 80% since the early 1980s. Furthermore, even lower prices are anticipated as well, as 'industry analysts see the cost will drop by an additional 20% to 40% by 2005.'

12.1 *Electricity from wind*

Nowadays wind power is not only the world's fastest growing energy source but it has also become one of the most rapidly growing industries, reaching sales of approximately $3 billion in 2008. In the early part of the next century major offshore developments would be likely to exist in northern European waters. Germany, the US, Spain, Denmark, India and Australia are undoubtedly among the world's leading nations regarding the acquirement of wind generated energy which is growing at an amazing rate. This will be the next considerable step for this sort of technology and will lead to a much more noticeable rise in decentralized electricity generation. Moreover, offshore wind has the capacity to deliver substantial quantities of energy at a much cheaper price in comparison to the other renewable energies. This happens because wind speeds are, generally speaking, higher offshore than on land.

Starting from 1999, global wind energy capacity reached the highest point of 10,000 megawatts, which is roughly 16 billion kilowatt-hours of electricity. In accordance with the American Wind Energy Association, the above wind energy is enough to serve over 5 cities the size of Miami. Although 5 Miamis may not seem important, if we make the predicted long steps in the close future, wind power could be one of our major sources of electricity. As we have already mentioned, without a doubt big countries such as Germany, the US, Spain, Denmark, India and Australia are among the world's leading nations regarding the acquirement of wind generated energy. Chris Flavin, a speaker at the World Oil Forum in Denver, Colorado, on October 30, 1998, had clearly stated that Navarro, Spain, is in fact using wind power to produce 23%of its electricity needs. Denmark today generates 8% of its electricity from wind power. Flavin, who is a vice president and senior energy policy analyst at the *Worldwatch Institute,* mentioned that wind generated energy is rising at a ferocious rate. Actually, in accordance with *Worldwatch Institute Online,* the world has made 'a new all-time record' as it has added 2,100 megawatts of new wind energy producing capacity in 1998, in other words, 35% more than it was added in 1997.

Based on an April 1999 press release, wind energy capacity has grown throughout the world at an annual rate of 25.7% in the course of 1990s, with the total doubling every three years and the cost of production dropping constantly as each doubling happens and economies of greater size can be realized. Christophe Bourillon, executive director of the European Wind Energy Association, noticed that Europe has come out not only 'as a world leader in wind energy development' in the 1990s but he also expects this to go on.

Regarding the wind industry in the US, the month of June 1999 is a sign of indicating the end of the year yet. Progressive state policies and increasing consumer requirement for 'green' (low-environmental-impact) power are the main cause for this 'wind rush' in accordance with the executive director of the American Wind Energy Association. Nowadays, many states are in need of that part of their energy production coming from renewable sources. Furthermore, utilities are now in a position to offer people the opportunity to buy green power at a premium over power from conventional. Environmentally-damaged sources like fossil fuels. In the majority of cases, wind, as one of the least-cost renewable energy sources, is the lead beneficiary. In addition, both utilities and policymakers are constantly astonished by the public's positive correspondence to the availability of this green power.

Bird mortalities on wind farms are a matter of concern. According to a study, 182 dead birds, 119 of which were raptors, were found in the Altamont Pass Wind Resource Area in California. In reply to the above, the wind industry has made a commitment to amend the equipment to make the area much safer for birds. Suggested ideas include decreasing the number of perches on turbines, turbines to be spaced far enough apart and certainly in the direction of migration, painting patterns on blades should be contrasted with landscape colors, and even broadcasting a radio frequency in order to keep birds away in total. In the meantime, while taking responsibility in this serious issue, the industry silently indicates the fact that many millions of species are killed per year for the purpose of acquiring and distributing of most conventional sources of energy.

As can be seen from the above, the pros of wind power outweigh the cons to a great degree. Even if it can only complement other sources of energy for the moment, it provides not only skilled jobs for humans in rural communities but also replaces environmentally harmful energy sources as it is inexhaustible as well. For that reason, there will never be a reason to be liable to embargoes or 'price shocks' that are brought about by international conflicts. In contrast to oil fields, wind energy is renewable, year in and year out, forever.

13. Global Renewable Sources of Energy

Nowadays, the implementation of Renewable Sources of Energy is proved to have an outstanding impact on human daily life while shaping the whole world in years to come. The Dubai Electricity and Water Authority (DEWA) in the middle of September 2017 awarded the 700-MW fourth phase of the **Mohamend bin Rashid Al Maktoum Solar Park** which is in south of Dubai, United Arab Emirates. According to DEWA, the concentrated solar power was awarded to a consortium making up of Saudi Arabia's ACWA Power and China's Shanghai Electric; the consortium also bid the lowest levelized cost of electricity energy at US$0.73/kWh. For that reason, they have already lowered the price of **solar power bids** in Europe and the Middle East. In addition, the Mohammed bin Rashid Al Maktoum Solar Park which will become fully operational by the year 2020, will generate 1,000 MW by 2010 and 5,000 MW by 2030.

Green Investment Group (GIG), formerly the Green Investment Bank, arranged in September 2017 a £38 million (US$51.6 million) debt facility for a new, large-scale merchant **waste-to-energy facility** that is near Knottingley in West Yorkshire, U.K. This specific investment is part of a £207 million (US$281 million) senior debt facility from a syndicate of lenders who are going to fund Wheelabrator Technologies' stake in FerrybridgeMultifuel 2 (FM2). When it will become fully operational, the 70-MW facility will produce electricity for both U.K. homes and businesses.

Furthermore, referring to a 2016 Bloomberg New Energy Finance (BNEF) industry research report, we should mention the **off-grid solar sector** should amount to $3.1 billion by the year 2020. As the **energy storage** sector that is determined to follow the same strong upward growth trend, the chances for development in the off-grid energy storage market are bound in developing and developed countries. Off-grid applications vary from homes and eco-resorts to remote lighting, telecom and community microgrids, as well. The usage of renewable energy sources such as solar and wind with battery storage are now in the position to generate reliable electricity for remote oil production sites. In case of **Colombia** for instance**,** the particular project involved building solar microgrids to produce power for five native communities which resulting in enhancing the quality of life of residents and commercial business activities.

On the other hand, **India's Low Tariffs have hurt Wind Turbine Makers** a lot because competitive bidding for **solar and wind power** has dropped tariffs and power producers are under a great pressure to renegotiate pricing. That hard bargain is possible to deter private companies from investing in reneable projects and unfortunately that has already begun to deal a huge blow regarding demand for equipment. The pace of capacity addition has decelerated this year. Wind turbine manufacturer **Suzlon Energy Ltd's** revenue fell 46% in the quarter ended June over the last 3 months and certainly ascribed the reduction to falling tariffs.

But even if larger companies may manage to surpass the slowdown, smaller units deal a great risk as far as their economic survival. In accordance with the decision from the UK Office of Gas and Electricity Markets (Ofgem), U.K. renewable energy company **Anesco's solar and storage projects** are going to be the first sites in the U.K. to qualify for support paid to accredited renewable energy generators for electricity generation supplied to batteries. Its three5-MW solar projects with I.1-MWh batteries now are approved under the Renewables Obligation scheme as **batteries can help** with system balancing and save consumers money by matching supply and demand.

In **South Australia 2016 Storm** proved to have clearly agitated renewable energy investment, as well. As a result, having grown confidence in the sector, South Australia is ahead of schedule to reach its 50% renewable energy target by 2025. Based on the statement of Assoc Prof Diesendorf, South Australia which constitutes about 40% of Australia's wind generated electricity, is obviously affecting Victoria, which has now set its own substantial renewable energy target inspiring confidence to create more **solar and wind farms.** The **Cerro Pabellon geothermal project** was also inaugurated in September 2017 in **Chile** by the Italian utility Enel and Chilean energy company ENAP. That facility, which is actually 4,500 meters above sea level located in the Atacama Desert and is consisted of 2 units each with an installed capacity of 24 MW, will assist Chile to diversify its generation mix.

Even if it is extending across Utah, Nevada and Arizona, today the biggest part of the **Mojave Desert's land** which is closely connected with **solar and wind power development** is in California. It is especially slated for 2 counties, Kern and San Bernardino and apart from the initial reputations, political differences and objections from local decision makers and residents, solar and wind companies became a part of the community and the public finally saw solar and wind as a part of the local economy.

Moreover, the **SunSpec Alliance** has taken the decision to play a central role by changing the way solar and storage can assist in firming up the grid through **SCADA**system (solar supervisory and data acquisition) which is typically required for **hydropower and wind power** but not for the solar industry. For that reason, state and local utilities in California and Hawaii are on the way to incorporate solar assets into their systems managed by SCADA also because of distributed energy resource **(DER)** standards like IEEE 20130.5. In this way, owners and operators will have the opportunity to develop low-cost SCADA for greater internal visibility into the plant operations while on the other hand SunSpec standards fix the location and interpretation of data on solar equipment, including inverters reducing the time that is required to map the specific equipment to the SCADA software. Closer relationship between operators and grid is built which is leading therefore to consolidation and management of individual plants into larger solar fleets.

Kouga Wind Farm is one of 28 wind farms approved by the Department of Energy in round one of the Renewable Energy Independent Power Producer Procurement (REIPPP) program. Situated approximately 70km southwest of Port Elizabeth- between Oyster Bay and St Francis Bay- it delivers 80 megawatts of grid-connected capacity in search of powering the country's low-carbon future. The 32-turbine farm at Kouga, operational since March 2015, generates at least 300 million kilowatt-hours (300GWh) of clean electrical energy annually, reducing in this way greenhouse gases around 270,000 tons. German wind turbine manufacturer Nordex was chosen for engineering, procurement and construction and began at the site in March 2013. The benefits that come from this huge project are amazing. South African citizens and local communities will be helped a lot in their daily life while a number of minimum thresholds and goals on job creation, local community ownership and socio-economic development have to be met and boosted. A new Industrial Policy Strategy was published in September 2017 by the European Commission aspiring to reinforce Europe's industry and make it more powerful and competitive.

Digitalization and industrial innovation are two of the most important pillars of the new Industrial Policy Strategy and this can be proved mainly by the great strides that have been made in both fields. Wind Industry gains ground more and more every day in many ways. In case of digitalization, sensors are nowadays fitted to wind turbines with a view to improve operations and maintenance. The size and output of turbines have been increased thanks to cutting-edge innovation while battery and storage solutions manufacturers that have been added to turbine portfolios enable wind energy to have a better control of its variability. According to WindEurope CEO Giles Dickson, stable policies and regulation, more ambition on renewables (a 35% target for 2030), investment in EU-based research and testing can make the big difference in the usage of alternative sources of energy.

Europe is becoming a worldwide leader in wind energy as it has got a 40% share of all wind turbines that are sold globally representing over 300,000 jobs and generating €72 billion in annual turnover. Wind energy completely satisfies the demand of 10.4% of the EU's power permeating in countries such as in Denmark at a rate of 42%, in Spain 20%, in Germany 13% and in UK 11%. Nowadays, wind is becoming the most competitive source of new power generation (onshore wind LCOE varies from €52 to €110/MWh based on Ecofyn 2015). Wind energy has already made major progress in the energy market, in technology development and cost reduction and its geographical reach. It has actually become a worldwide success story as over 70 non-European countries have emphasized this sort of energy in their national climate and energy plans, while more than 90 countries are using wind turbines to produce power for their needs. The **Global Wind Summit** which is going to be held in Hamburg in 2018 reflects this real breakthrough. In September 2017, WindEurope and the **Industry Advisory Panel of the International Energy Charter** jointly organized an event on "Promoting and De-risking Renewable Energy Investments". Many energy companies, government representatives, financial and legal institutions took part in this very significant event.

Viable business models and revenue streams were particularly serious issues that should be widely discussed apart from the legal certainty and its great role in the industry development. At this point we should mention the crucial role of the **Energy Charter Treaty** which provides a multilateral framework for energy cooperation and is unique under international law. Up to now, the Treaty has been signed or joined to by 52 states, the EU and Euratom.

The remarkable results of the latest **UK CfD** (Contract for Differences) where offshore wind submitted record bids of £57.50 per megawatt hour including the costs of grid connection highlight in fact the big strides by offshore wind in the latest years. 3.2 GW of new capacity to the **UK,** sufficient for covering the needs of 3.3 million homes will be provided by the winning offshore wind projects. As a result, revenue stability, low cost of finance and low cost to energy consumers is gained by the UK's CfD model. **Offshore wind industry** provides strong evidence that can create investment and support high-skilled jobs in the UK; ambitious commitments on future development volumes for offshore wind from the UK and other European Governments are absolutely necessary.Talking about leading competitors in Europe's energy transition, a quarter of Portugal's electricity consumption comes from **wind energy** as it has already more than 5 GW of wind energy installed. **Portugal** has also committed to supporting the industry in many of the aspects it is requesting for on the **Clean Energy Package**. The Enercon and Senvion manufacturing sites in Portugal have seriously assisted in local economic growth. Planning to develop a 24 MW floating offshore wind farm in 2018-2019 will give a great boost to the country's new investments.

Moreover, **Finland** opened its first ever **offshore wind farm** in September 2017. The project of the 42 MW Tahkoluoto wind farm which received the Finnish feed-in-tariff (83,5 €/MWh for 12 years) and a €20 million demonstration subsidy, is 1,2 kilometers from shore and at a water depth 9 meters. It is designed for icy weather conditions while utilizing technological solutions for arctic conditions. From now on, it is sure that project can provide a ready concept for planning and building offshore wind power on an industrial scale.

Estonian Presidency of the EU Council has organized a conference on **Europe's Future Electricity Markets** in order to discuss the Clean Energy Package while promoting networking with senior officials. Among other points, the digitalization of the energy sector that should be accelerated and the **E-Energy Tallin declaration** supported by WindEurope were also discussed. Enhancing a better cooperation between the public sector and companies offering consumers best prices and service providers through digital solutions can lead to support better data and also support the creation of inclusive flexibility markets.

Scottish government in July 2017 greatly supported its position regarding its low carbon and renewable energy economic policy. It stated that renewables are the single largest contributor to electricity generation in the country giving specific emphasis on the development of **onshore wind.** As a result, **EDF Energy Renewables** (EDF ER) has already announced that bought 11 wind farm sites in Scotland from development and asset management Partnerships for Renewables. The Scottish sites will have a potential capacity of 600 MW.

In accordance with **IEA**, onshore and offshore wind will be the backbone of the future power system due to the fact that almost 30% of Europe's power demand will be covered by 2030 by wind energy. Long term decarbonisation, energy security and competitiveness objectives can be achieved via implementing realistic and ambitious post-2020 renewables policies that can also increase the job count to 688,000 till 2030. 70 countries, including Greece, have already signed the **Paris Climate agreement** to set goals to limit temperature and high carbon emissions promoting wind and other renewables. On the other hand, reducing policy ambition and poorly managed shifts to new forms of support mechanisms and retroactive changes have created challenges that have to be seriously dealt. This happens firstly because new wind investments are mainly concentrated on a smaller number of markets (Germany accounting for 40% in 2016). Furthermore, only 7 Member States out of 28 have post-2020 plans for renewables.

Nordsee One GmbH, which is owned by Northland Power Inc. (85%) and innogy SE (15%) successfully, completed turbine installation in just 7 months. Each Senvion 6.2M126 wind turbine (of the 54 wind turbines) is approximately 150 meters tall. The 332 MW offshore wind farm that successfully completed it has been scheduled to start its commercial operations till the end of 2017. Once it is fully completed, the Nordsee One offshore wind farm will provide the equivalent of approximately 400,000 residences with green electricity. The wind farm will be functioned and serviced by the operation and maintenance base in Norddeich (Germany, Lower-Saxony).

"The wind is back in Europe's sails" **European Commission President Mr. Jean-Claude Juncker** has said in his annual state of the union address. It is obvious that investments in clean and flexible power on the large scale should be provided to deliver Europe's energy transition. Sustaining EU leadership in wind requires a strong industrial policy and publicly funded R&I at European and national level covering technology and system integration. We should also keep in mind that leveraging the cost-effective investments that are needed for the energy transition needs stable policies and the mitigation of investor risk that comes from policy changes.

14. Digital Wind Farms – The Evolution of Technology

General Electric (GE) has recently launched its **Digital Wind Farm in India** that encourages the wind industry to go ahead into the future by combining the smartest most Advanced Hardware with the power and flexibility of the Industrial Internet.

The concept is consisted of a modular, 2-megawatt wind turbine that could be easily customized for exact locations and software that closely observes and optimizes the wind farm as it produces electricity.

In this way, a wind farm's power production could be pushed up by as much as 20% and create $100 million in extra value during the lifetime of a 100 megawatt farm. **The Industrial Internet** is a digital network built on the **Predix platform,** a cloud-based software platform. In fact, it is the foundation for all GE's Industrial Internet applications that also includes its **specialized cyber security protection** for operational technology. It turns real-time data into insights for better, faster decision making in order to optimize the owner fleet's performance. It developed by GE that provides a digital infrastructure for the wind farm making scientists able to connect, collect, visualize and analyze unit and site level data. GE supports that it could add more than $10 to $15 trillion to global GDP in effectiveness gains during the next two decades.

GDP in effectiveness gains during the next two decades.

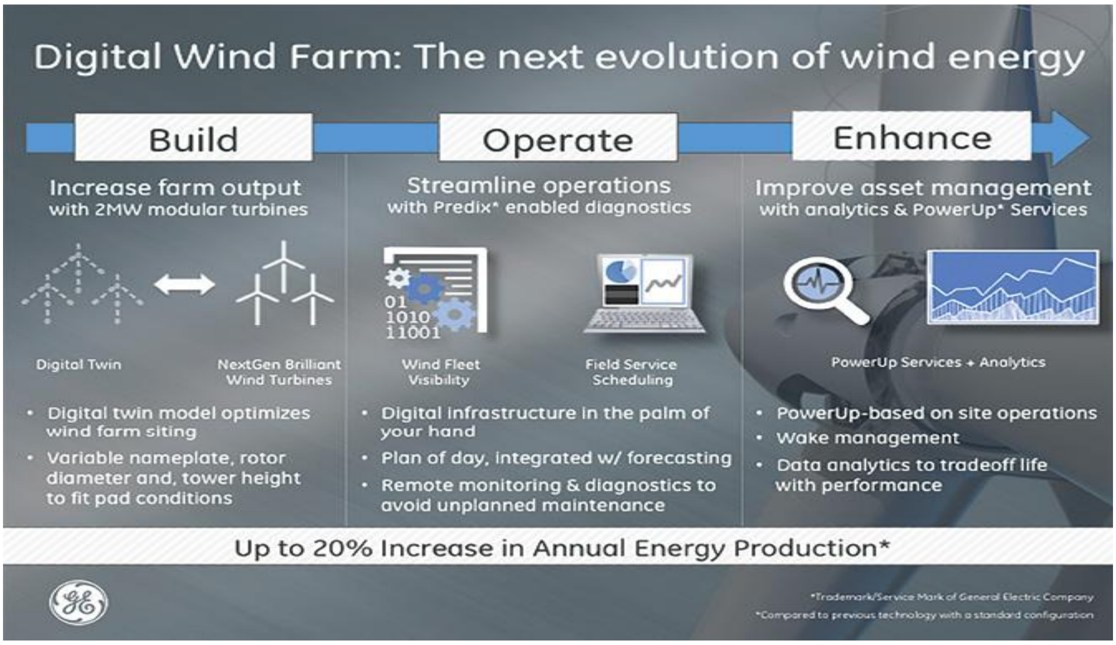


Figure 10: Digital Wind Farm (General Electric)

Every wind farm has got its own unique profile which reminds us of DNA or a human fingerprint. Keith Longtin, general manager for wind products at GE Renewable Energy stated about Digital Wind Farm" We thought if we could capture data from the machines about how they interact with the landscape and the wind, we could build a digital twin for each wind farm inside a computer, use it to design the most efficient turbine for each pad on the farm, and then keep optimizing the whole thing".

Moreover, the digital wind farm is a **wind energy ecosystem** which is dynamic, connected and adaptable as it enables wind turbines to have up to 30% more power output than the previous models of GE. The applications that are included until today are Wind PowerUp Services, Wind Energy Forecasting, PulsePOINT Condition Monitoring System and WindCONTROL Farm Control System. In addition to business optimization, GE also developed 2 new apps that will help streamline wind farm operations. The apps are capable to combine a selection of desperate data sets, including SCADA information, diagnostic readings, weather conditions and even geolocation data, to co-ordinate and put in order of importance daily maintenance schedules across a wind farm site.

The digital wind farm is truly going to be a transformational technology that is going to allow Indian customers to participate in the beginning of a significant phase in technological innovations for the renewable energy market.

15. Offshore Wind Power

It is remarkable indeed that an overall amount of 2,219 MW of new **offshore wind energy** was installed across seven markets in the world in 2016, and despite the fact that numbers were decreased 31% in comparison to 2015, the future looks well-promising. Today, there is 14,384 MW of installed offshore wind energy capacity in 14 markets globally. At the end of 2016, nearly 88% (12,631) of all offshore wind installations were set up in waters off the coast of 10 European countries. The remaining amount of 12% of the installed capacity is located largely in China, followed by Japan, South Korea and the USA.

According to the latest **GWEC's Global Wind Report Chapter on Global Offshore**, the UK is the world's largest offshore wind market and represents just fewer than 36% of installed capacity, followed by Germany in the second place with 29%. China passed Denmark in 2016 to accomplish 3rd place in the worldwide offshore rankings with 11%. Denmark now accounts for 8.8%, the Netherlands 7.8%, Belgium 5% and Sweden 1.4%. Other markets including Finland, Ireland, Spain, Japan, South Korea, the USA and Norway make a positive contribution to the balance of the market. The spread of the offshore industry has started beyond its northern European home to North America, East Asia, India and elsewhere. Furthermore, apart from the first US **offshore wind farm** put into service in 2015, there is also a refreshed push in China and an ambitious program in Taiwan. It is obvious that global growth has seriously began to launch in the next few years, while at the same time Europe continues to dominate in the foreseeable future. Nevertheless, it should be mentioned that in 2016 there was a significant decrease in offshore wind prices.

GWEC's Global Wind Report Chapter on Global Offshore states "It started with the Dutch tender for Borssele 1 & 2 in June coming in at a €72/MWh, well below expectations; followed by a Danish near shore tender in September at €64/MWh. This was followed in November with the winning bid for the Danish Krieger's Flak project coming in at an astonishing €49.90/MWh; and then Borssele 3 & 4 in the Netherlands coming at a €54.50/MWh in December". Nowadays, the situation as it is seen is very bizarre because **offshore is cheaper that onshore!**

There are various reasons why this is happening: the maturing process of the industry, the evolution and maturation of the technology and its management, the growing investor trust and the introduction and development of a new generation of 6-8 MW (and now 9 MW with the up-rating of the **Vestas V-164**) machines with huge swept region and prodigious output.In accordance with the **Global Wind Energy Council (GWEC**) and its flagship publication Global Wind Report, regarding the Annual Market Update at Windergy, more than 54 GW of clean renewable wind power was installed across the worldwide market in 2016. Today, it is composed by more than 90 countries; including 9 with more than 10,000 MW installed and 29 countries that have now passed the 1,000 MW mark. Cumulative capacity increased by 12, 6% to come to a total of 486.8 GW.

"Wind power is now successfully competing with heavily subsidized incumbents across the globe, building new industries, creating hundreds of thousands of jobs and leading the way towards a clean energy future", said GWEC Secretary General Steve Sawyer. He continues stating that "We are well into a period of disruptive change, moving away from power systems centered on a few large, polluting plants towards markets increasingly dominated by a range of widely distributed renewable energy sources. We need to get to a zero emissions power system well before 2050 if we are to meet our climate change and development goals".Wind power penetration levels keep on rising, led by Denmark pushing 40%, followed by Uruguay, Portugal and Ireland with well over 20%, Spain and Cyprus around 20%, Germany at a 16%; while the big markets of China, the US and Canada get 4, 5.5, and 6% of new wind power from wind, respectively. Based on GWEC's rolling five year prediction, almost 60 GW of new wind installations in 2017 will increase to an annual market of about 75 GW by 2021, bringing cumulative installed capacity of over 88 GW by the end of 2021.

Furthermore, growth will be led by Asia. China is the country that will go on leading all markets while India set a new record for installations during the previous year and, as a result it is much interested today to meet the government's ambitious goals for the sector. Moreover, in the region there are a big number of most promising new markets with great potential. The dramatic lowering prices for offshore wind, the year's most exciting new development can give a big boost to 2020 targets based on the Europe's steady situation and powerful market fundamentals in North America. While Europe will keep on leading the offshore market, the low prices have attracted the attention of policymakers in the whole world, especially in North America and Asia.

Steve Sawyer also stated that "offshore wind has had a major price breakthrough in the past year, and looks set to live up to the enormous potential that many have believed in for years. We see the technology continuing to improve and spread beyond its home base in Europe in the next 5-10 years".

In spite of Brazil's political and economic distress, other countries in the area have accelerated to fill the gap, specifically Uruguay, Chile and the area's most exciting new market in Argentina. Africa will have a very good year in 2017, led by Kenya, South Africa and Morocco. The future of wind looks bright and well-promising, indeed. After a lull on the part of the Australian market, it seems to come roaring back with many projects to be carried out over the next few years.

To conclude, it is true that there is much confidence in the wind power market, as the technology keeps on improving, prices continue to lower prices and the call for clean, renewable power to reduce emissions, clean air and create new jobs and industries only becomes stronger year in, year out.

Offshore Wind Energy System Part 2 analysis of case study of thesis

16. The Offshore wind farm of the Thesis

The contractor of the offshore wind farm is the Wind Technology S.A, a company with a large portfolio of renewable energy Investments across Greek mainland. The board of this company decided to invest in the fast- moving sector of offshore wind farms/technology. On March of 2016 they contacted and order the Green Advisors LTD, a consulting and Engineering Procurement Company (EPC) in order to decide if such an installation in Greece is feasible and profitable. The Green Advisors company with a specialized team of Engineers, Risk Analysts and Economists for six months occupied with the realization of this feasibility report. Afterwards, at the headquarters of Wind Technology S.A, a team of Green Advisors S.A, with head of the team Mrs.N.Laurence, presented the deductions and if this investment is really profitable for the company, analyzing basic financial indicators. Next pages will show if the investors undertake the decision to support the first offshore wind farm in Greece. The following chapters illustrate all the parts of the analysis, starting with the components.

16.1 *Components*

16.1.1 *Meteorological Systems*

Throughout the planning stages a meteorological met tower (mast) is the first structure that is installed. Its purpose is to assess the meteorological environment and resource data within the project area. A mast consists of a foundation, a platform with boat loading, navigation lightning and marking, meteorological and other instrumentation, and related equipment. A buoy might also be used, too. Intersecting the wind with an anemometer a mast can collect wind data at multiple heights in order to depict the project area’s meteorology.

Data is gathered by sensors regarding vertical profiles of wind speed and direction, ocean current velocity and direction profiles air temperature and barometric pressure and also sea water temperature. The data that comes from the meteorological mast assists in testing power performance, performing due diligence evaluation and facilitating estimates of operation maintenance management. Permit authorizations for the installation of monitoring systems are acquired via the U.S. Army Corps of Engineers (Nationwide permits 5 and 6), the U.S. Coast Guard (private aids to navigation) and the BOEMRE (limited lease) or state leasing agencies.

16.1.2 *Support System*

The support system concerns the foundation, transition piece and scour protection. The main goal of the foundation is to give support to the turbine. A transition piece is attached to the foundation to absorb tolerances on inclination and make less complex the tower attachment. Scour protection assists in ensuring that ocean conditions do not deteriorate the mechanical integrity of the support system.

16.1.3 *Foundation*

Foundation technology is designed in accordance with site conditions. The foundation type and design is influenced by the maximum wind speed, wave heights, water depth, and surf properties.

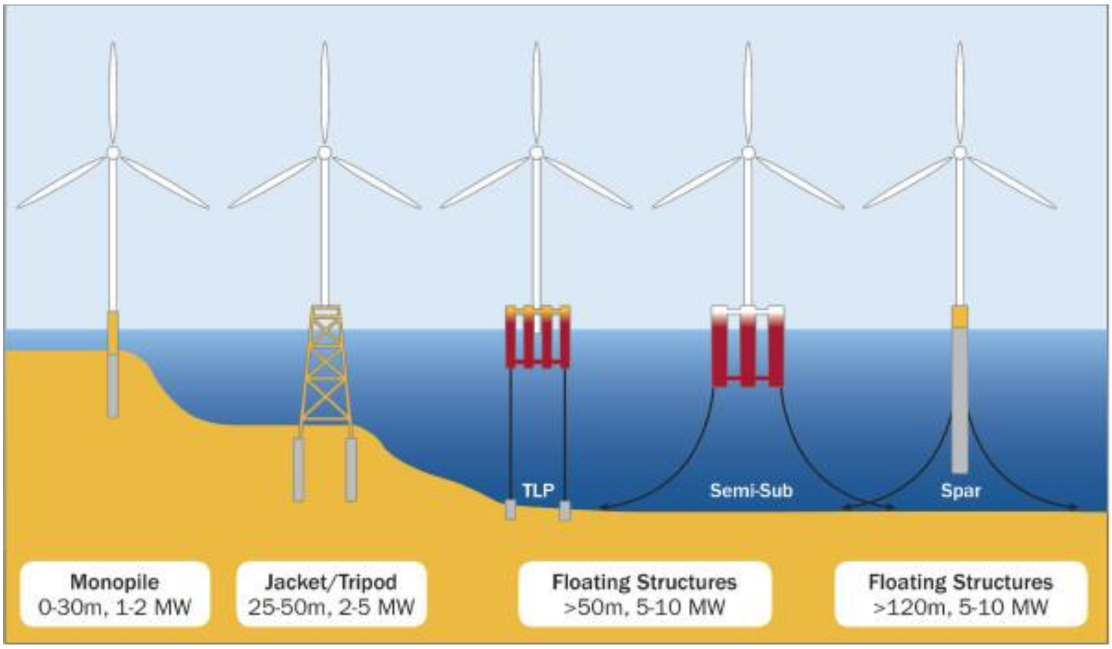


Figure 11: Types of Foundations (Research Gate)

Among key components are the size and weight of the turbine and the tower. Within a wind farm, each foundation is adapted to the water depth at its specific location.

Foundations are prefabricated onshore in one piece; afterwards they are carried offshore by barge or other vessel and launched at sea. They are set on bottom by a crane or derrick barge. In offshore wind farms, monopiles, jackets, tripods and gravity foundation are the four basic types of foundations that have been used. Furthermore, a single 2.3 MW demonstration turbine has been installed on a floating foundation.

16.1.4 *Monopiles*

Nowadays, monopoles are the most common foundation in shallow water (<20 m) because of its lower cost and simplicity, but also because they are restricted by depth and subsurface conditions, they are probably to decrease in popularity in deeper water.

Monopiles are large diameter, thick walled, steel tubular that are driven (hammered) or drilled (or both) into the seabed. Hydro-hammer or vibro-driving devices are also used in monopile piling. Outer diameters usually vary from 4 to 6 m and typically 40–50% of the pile is inserted into the seabed. The design load, water depth, soil conditions, design codes and environmental conditions are the factors that the thickness and the depth of the driven piling are depended on. Pile driving is more effective and less expensive in comparison to drilling. Nevertheless, in emerging markets, such as the U.S., and as regards the near term future, monopoles are expected to be heavily employed. Monopile is the most used foundation type in Denmark, Germany and UK, as well.

16.1.5 *Tripods*

Tripods that are typically until 30/40 m are not much common as they are heavier and more expensive to manufacture in comparison to monopoles, consist of a central steel shaft connected to three cylindrical steel tubes via which piles are driven into the seabed as they are more effective in deep water. The Alpha Ventus project is the only wind farm in operation that employs tripod foundations.

16.1.6 *Jackets*

Jacket foundations are an open lattice steel truss template consisting of a welded frame of tubular members extending from the mudline to above the water surface. A very impressive example is the steel lattice structure (welded pipes Ø 0.5-1.5 m) from Oil & Gas industry ~1000 tons (>1km welding).Piling is driven via each leg of the jacket and into the seabed or via skirt piles at the bottom of the foundation, to secure the structure against not straightforward forces. Due to the fact that jackets are robust and very heavy structures, expensive equipment to transport and lift is absolutely necessary. Jacket foundations, until now, have not been widely used because of the preference for shallow, near shore environments.

Heavy turbines (>5MV) are necessary for the suitable structure regarding deep water (<50-60m). Small leg monopiles are driven in the seabed (Ø 1 - 2.5m). Two of the deepest developments, Beatrice (45 m) and Alpha Ventus (30 m) which support large 5 MW turbines, have used jackets that also give support to offshore substations. Beatrice was actually the very first offshore wind installation (2 x Repower 5MW – 45 m water depth).

Among other **advantages,** as jackets are of light weight and stiff structure, they have better global load transmission compared to monopiles. Large variations in water depth can also be covered via cantilevering piles or modifying the geometry. Rarely scour protection is needed, as well. In addition, based on official studies, there is structural redundancy and low soil dependency. Generally, there is also good response to wave loads even if little sensitivity to large waves and limited dynamic amplifications of loads because of high stiffness should be also mentioned. Limited storage area compared to GBF and faster fabrication comparing to GBFs (serial protection) are also much significant. Jackets offer better quality control and easy decommissioning, too.

On the other hand, there are some considerable **disadvantages** when using jackets. Firstly, due to complexity of fabrication there should be a large number of joints compared to other latticed structures. Logistical issues because of the templates (pre-piling case) can be appeared, too. Complex connection to transition pieces and high manufacturing lead-times should also be taken into great consideration. Moreover, most of the times there is no standardized design that leads to long certification processes. Jackets have the capability to be used in deep water (100s of meters) even if economic considerations are probable to restrict their deployment to water less than 100 m.

16.2 Jacket or Lattice Structures

In fact, there are many variants of the three or four-legged jacket/lattice structure that usually composing of corner piles interconnected with bracings with diameters up to 2m. While the tubular joints are welded, the soil piles are driven inside the pile sleeves to the necessary depth in order to gain enough stability for the structure. These types of structures are esteemed well suited for sites with water depth varying from 20-50m in accordance with the DNV. At the South Korean offshore wind farm, Tamra, the minimum is 3.5m and the maximum depth for an operational project is 45m on the Beatrice Demonstration project, as we have already mentioned above. Of course, other projects in the planning pipeline are suggested using jackets in water depths up to 60-70m but these have not been consented yet.

The transition piece connects the main jacket with tower of the wind turbine. Loads are transferred via the members mainly in axial direction while the large size of base of the jacket structure gives large resistance to overturning. The work platform, ladders and stairs, j-tube, cables, access systems and corrosion protection systems are included in the secondary steel.

Those who are in favor of the jacket structures strongly support the following: low wave loads comparing to monopiles (the jacket structure is very still and the area dealing with the wave movement is smaller than monopiles), and fabrication expertise is available to a large extent partly because of Offshore Oil and Gas industry supply chain. On the other hand, there are those who are against due to high initial construction costs and possibly higher maintenance costs whilst the transportation is reasonably difficult and expensive.

16.2.1 *Installation*

The jacket structures are generally attached to the seabed via piles. There are two methods of installing the foundation of the jackets: pro-piling and post-piling.

16.2.2 *Pre-piling*

Throughout pre-piling, to ensure the correct positions of the piles and inclination subsea templates are used. When the piles are inserted into the seabed then the jacket is lowered and fitted into the piles.

Supporters of pre-piling state that pile sleeves and mud mats are reduced on the jacket while piles can be installed well prior to jacket and wind turbine generator installation. Fabrication of jacket can be also carried out at the same time with piling operations and seabed variations can be leveled by changing pile stick-up. Moreover, verticality of jacket is easily arranged in this way as seabed leveling ensures standardization of jackets. The pre-installed pile method was firstly used in the wind farm of Alpha Ventus. The usage of a centre template could secure the position on seabed, after which a slot was moved around the centre template for the four pile locations. The piling hammer can be lowered on top of the pile while the slot supplies vertical stability for the piles. Piles were loaded on –board and up-ended before lifting the piles into the slot on the seabed and hammered down using a subsea hammer. Alpha Ventus assisted in setting up those pre-installed piles raises the operational weather window and decreases installation time and risks. Jacket foundations have also been used in Thornton Bank Phase II, Ormonde and NordseeOst Offshore wind farms.

16.2.3 *Post-piling*

This method has to do with the installation of piles via the sleeves that are located on the jacket legs. Grouting is commonly used to fix the sleeves to the piles and provides the connection to transfer the loads from the jacket leg to the pile.

In addition, the post-piling process (even if it has not been typically adopted for usage on offshore farms) needs mud-mats that transfer loads to the seabed acting as a support foundation while the piles are being installed. For that reason, it is only been used at the Beatrice Demonstrator Offshore Wind Farm.

16.3 Beatrice Demonstrator Project

The Beatrice Demonstrator Project contained two 5MW turbines that were established in 45m water depth. The export cables form a connection between the turbines and the nearby Beatrice oil field production platform.

The turbines were installed in two phases. The jacket support structure was transported on a barge to the offshore area. On site, two cranes lifted the 730t structure off the barge were used by the heavy lifting vessel Rambiz and tilted it into an upright position. Afterwards, the support structure was lowered onto the seabed and leveled.

The second part of the installation procedure contained installing the entire wind turbine, containing also the turbine tower in one lift. The turbine was pre-assembled onshore on top of a soft landing system and lifted off the quayside. The turbine was also joined with the support structure at the offshore location and finally the lifting frame and the soft landing system were removed to complete the whole installation procedure. The Beatrice Demonstrator was the first wind farm in using jacket foundations.

16.4 *Concrete Structures*

Gravity Based Foundations (GBF or GBS) that are typically until 30/50 m are concrete structures which use their weight to abstain from wind and wave loading. Unique fabrication facilities that can accommodate their weight (either dry docks, dedicated barges or reinforced quays) are required for Gravity foundations. They have been used at many offshore wind farms, including Middelgrunden, Nysted, Thornton Bank and Lillgrund. Gravity foundations are cheaper to build comparing to monopiles but the installation costs are much higher mainly due to the deed for dredging and subsurface preparation apart from the usage of specialized heavy-lift vessels. In Thornton Bank there are the deepest gravity foundations that are operational. Gravity foundations that might also have an asset in ice – prone areas, are probable to be used where piles cannot be driven and the area has dry-docked facilities for concrete construction. In the North Sea, the usage of the gravity foundations in the offshore oil and gas industry is obvious; on the other hand, in the U.S. there has been neither use of concrete structures for offshore oil and gas operations nor clear plan to use them in offshore wind development. In Europe, gravity foundations will possibly keep on filling a significant niche for shallow to mitigate water depth areas where drivability is a matter of concern. Nevertheless, they are unlikely to be used in U.S. waters.

16.5 *Floating Structures*

As water depth rises, the usage of a steel platform will be restricted by economic concerns. In the offshore oil and gas industry, the water depth limit for fixed platforms is about 450 m (1,500 ft) but in the offshore wind industry the limit is possibly to be less than 100 m due to economic conditions. Floating structures consist of an anchoring system and a floating platform. Floating turbine foundations are in many alternative designs but all these variations are on the spar and tension-leg concepts in the oil and gas industry. Floating foundation is mainly used in offshore Norway, Scotland, and Ireland and in the Mediterranean Sea. Among others, installation should require less specific vessels even if there a possibility to assemble both turbine and plateform onshore (port) and afterwards tow them out on site. Concerning challenges on the other hand, there should be much consideration as for platform motions, moorings, dynamic electric cable and also face the possibility to have higher sea states due to higher winds from shore.

The Hywind concept developed by StatoilHydro is towed horizontally to a fjord and partially flooded and righted. A pilot turbine was placed in waters off Norway in 2009 while the foundation itself consists of an 8.3 m diameter, 100 m long submerged cylinder secured to the seabed by three mooring cables. Additional ballast was also added and the turbine installed on top. While the assembled turbine was towed out to sea, the anchors were placed.

Founded upon the tension-leg platform, Blue H has developed a deep water concept. A prototype has been deployed off the coast of Italy and another one is planned off the southern coast of Massachusetts. The Blue H concept is made up of a two blade turbine placed on top of a buoyant, semi – submerged steel structure connected to a counterweight on the seabed. Plans have to do with assembling the turbine and foundation onshore and towing it to the offshore site.

16.6 Transition *Piece*

After the foundation is fully installed, on top of it a transition piece is placed to create a level platform. Transition pieces pass through most of the water column but they do not rest on the seabed as boat fenders, access deck, access ladders and handrails are attached on the outside. Regarding monopile foundations, the gap between the pile and the transition is regularly filled with cement grout. As for jackets and gravity foundations, transition pieces are set up in port and would not require a separate offshore lift and in case they comprise boat landings, electrical conduits or other accessory components as these are installed elsewhere on the foundation.

16.7 *Scour Protection*

Scour which is about the removal of sediment from the area around the base of a support structure, may lead to structural instability when a structure is placed in a current and the seabed is erodible. Scour protection requirements base on the current and wave regime at the site, substrate and foundation type.

To address the problem low tech and relatively inexpensive methods are usually enough. Commonly employed measures of scour protection contain dumping rock of various grade and placing concrete mattresses around the foundation. In case of monopile foundations, a layer of small rocks might be installed earlier or following pile driving; later, after cabling is installed, large cover stones might be placed around the foundation. Important scour protection is absolutely necessary for monopiles, gravity foundations and tripods while piled jackets need little or no scour protection.

17. Wind Turbine Interconnection

Offshore turbines vary from 2 to 8MW. Component size and weight is different according to the electrical capacity of the turbine, the rotor dimensions and the selection of blade, hub and nacelle material and equipment. Turbines are a set up commodity but offshore technology is in the early stage of development and will keep on developing. In 2011, Vestas presented plans for a 8 MW offshore turbine and Siemens installed a prototype 6 MV gearless model. Plans concerning installing a prototype 10 MW turbine in late 2012 are dominated.

17.1 *Electricity Collection and Transmission*

Generally, cables connect the turbines and the wind farm to the electrical grid. Additionally, based on the configuration and layout of the wind farm, collection cables connect the output of strings (rows) of turbines. The output of multiple collection cables is combined at an ordinary collection point or substation for transmission to shore.

17.2 *Inner – Array Cable*

The inner-array cables actually connect the wind turbines within the array to each other and to an offshore substation if present. The turbine generator is usually of low voltage (less than 1kV and often 500 – 600 V) and is not high enough for direct interconnection to other turbines. Furthermore, a turbine transformer increases the voltage to 10 – 36 kV for cable connection while inner-array cables are connected to the turbine transformer and exit the foundation close to the mudline. Cables are usually buried 1-2 m below the mudline and are connected to the transformer of the next turbine in the string. The power that is carried by cables rises as more turbines are connected and the cable size or voltage may go up to handle the increased load. Installation of connection cable is done in separate steps from turbine to turbine.

The required cabling depends on the layout of the farm, the distance between turbines and the number of turbines.

17.3 *Export Cable*

The use of export cables is to connect the wind farm to the onshore transmission system and is usually installed in one continuous operation. Export cables might require scour protection even if they are buried to prevent exposure in some places. At the beach, cables come onshore and might be sliced to a similar cable and/or connected to an onshore substation. The cable route, time and cost is most of the times are determined by factors like water depths along the cable route, soil type or coastline types. At the onshore substation or switchyard, energy that comes from the offshore wind farm is delivered to the power grid. Transformers are used to match the point of interconnection (POI) voltage if the (POI) voltage is different from the submarine transmission. Otherwise, the wind farm is directly interconnected to a switchyard. Power produced is actually metered and purchased through a PPA with a local utility or entering the Independent System Operator's merchant market. Export cables are consisted of three insulated conductors protected by galvanized steel wire. When there is no offshore substation installed, medium voltage cables are used and usually range between 24 and 36 kV. On the other hand, high voltage cables are typically 110 – 150 kV and are mainly used with offshore substations. These kinds of cables have the capacity to carry more power comparing to a medium voltage cable but are much heavier and wider in diameter. High voltage cable might weigh 50–100kg/m while medium voltage cable might weigh 20-40 kg/m.

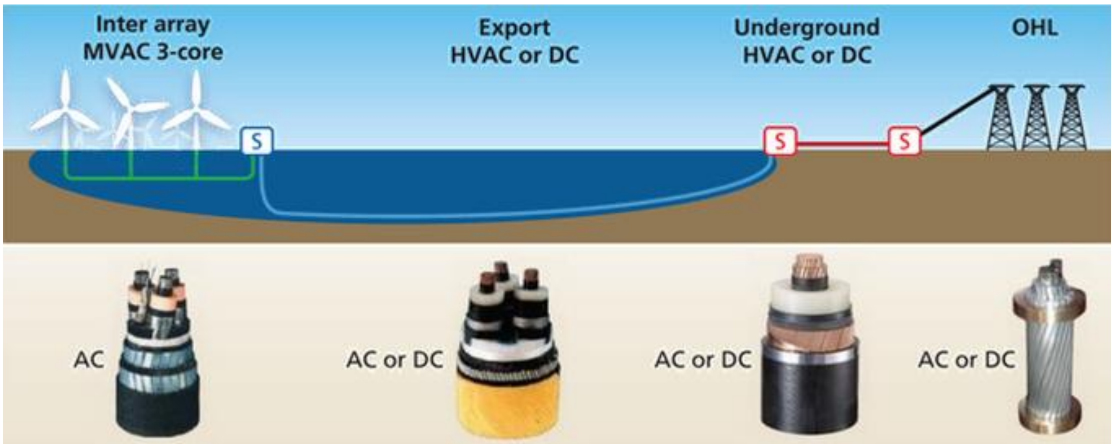


Figure 12: The four Types of Cables that used in Offshore Farms (Renewable Energy Federation)

17.4 *Offshore Substation*

The main goal of an offshore substation is to raise the voltage of the electricity produced at the wind turbine to minimize transmission losses. The substation is sized with the suitable power rating (MVA) for the project capacity and increase the line voltage from the collection system voltage to a higher voltage level usually that of the POI. All offshore wind farms need substations even if they are not all located offshore. The need for offshore substations depends on the produced power and the distance to shore that defines the tradeoffs between capital expenditures and transmission losses. The components of offshore substations contain voltage transformers, switchgear, backup diesel generator and tank, j-tubes, accommodation facilities and medium- and high- voltage cables.

Within the wind farm the substations are set up at a location that minimizes export and inner-array cable distance. Foundations similar to those used for turbines are set up for substations are usually 500 tons or more. Onshore substations also contain equipment to monitor power quality, like voltage stability and harmonic disturbances while SCADA systems allow the behavior of the entire system to actually monitored and controlled.

Figure 13: The Offshore Substation (4C Offshore)

17.5 Commissioning

Commissioning is related to the activities when all components have been installed but before commercial operations begin. Electrical testing, turbine and cable inspection and relevant quality control activities are also included. To enable the turbine controllers to be accessed remotely from the control room the communication and control systems are tested, as well.

18. Choosing the Suitable Wind Turbine

18.1 *Market Searching*

For the aims of the realization of the 400 MW Offshore Wind Farm, a market research was absolutely necessary. The criteria to choose the most efficient turbine were actually the comparison of the most powerful and effective marketplace machines. The following data offer a comparison based on the best options for the investment. The scope of this thesis is academic. For this reason, the chosen turbine will have the features of the best option and will not be the exact product.

The present titans of the wind power industry are going to be fully described while they are still in production or scheduled to begin very soon. Their power ratings vary from 5MW to 8MW-plus while rotor diameters reach up to 180 meters. However, the 7MW Samsung and Mitsubishi Heavy Industries Sea Angel machines are some of the largest turbines that have been omitted from our study due to their delayed progress.

MHI Vestas V164 9.5MW

The fortunes of the MHI Vestas joint venture seriously rely on the success of this model which was created in April 2014 and, nowadays, is the biggest wind turbine in serial production. At first it was announced by Vestas as a 8MV unit in 2011, the V164's growth concurred with a very dramatic time period in the Danish firm's history. Joining forces with Mitsubishi Heavy Industries was of a crucial importance in order to become capable to continue development and begin production of the V164. The blades are 80 meters in length and weighing 33 tons apiece are mostly made at the company's Isle of Wight facility in the UK. The first project made use of the V164, Dong Energy's Burbo Bank Extension in the Irish Sea. That turbine has already been chosen to power part of the Walney Extension project as it is going online in summer 2018.

Power rating *8MW* ***Rotor diameter*** *164 m* ***Drivetrain*** *Medium-speed geared* ***IEC Class*** *S*

Adwen A –180

The Adwen AD–180 is setting a new benchmark for blade length at 88.4 meters – 10% longer in comparison of the MHI Vestas V164. Both Gamesa and Areva JV partners were capable to draw on some experience with offshore turbines. Adwen AD5-116, not excepting the 400 MW Global Tech 1 project in the North Sea, is in operation at three German offshore projects. The new 8MW turbine does build on the design of the Gamesa unit, concerning to the tube-shape medium –speed drivetrain. The turbine has been chosen for three of France's first six offshore projects all of about 500 MW. However, Adwen is at present part of the lately-formed Siemens-Gamesa Energy manufacturer so the future of 8 MW platform is still not clear.

Power rating *8MW* ***Rotor diameter*** *180 m* ***Drivetrain*** *Medium-speed geared****IEC Class*** *lB*

Siemens-Gamesa Renewable Energy SWT-8.0-154

Siemens has managed to upgrade 2 times (a 6MW unit first seen in 2011) with a rotor diameter of 120 meters) the direct-drive offshore turbine for a power rating of 8MW with an extended rotor diameter of 154 meters which will produce 10 % more energy than its 7MW predecessor.

Officially, the operational life of the 6MV began in 2015 with the starting up of Dong's 210 MW Westermost Rough project off the north-east coast of England. Furthermore, it used at the UK's Dudgeon (402MW) and Germany's Gode Wind 2 (252MW) projects. The following 7MW was also used for large projects such as the 1.2 GW Hornsea project off England's east coast. The 329 MW eastern phase of Dong's Walney Extension used the same turbine while MHI Vesta'sV164 provided the hardware for the 330 MW western phase. Undoubtedly, Siemens has dominated the offshore market via its 3.6MW turbine.

Power rating *8MW* ***Rotor diameter*** *154 m* ***Drivetrain*** *Direct-drive* ***IEC Class*** *lB*

Enercon E-126 7.5 MW

The only onshore turbine to be qualified for this list is actually the Enercon's E-126. A total of 87 6MW and 7.5MW machines are today operational not excepting 38 E126s which are set up at the Noordoostpolder site in the Netherlands. The pre-fabricated modular tower comprises 35 tapering concrete rings and one steel yaw-bearing connector with a diameter of 14.5 meters at the ground narrowing to 4.1 meters at the top.

As a result, it offers the turbine a hub height of 135 meters and a tip height of 198.5 meters. We should also mention that the segmented steel-composite blades are not elaborated in length for a rotor diameter of 127 meters. Enercon has taken the decision to steer clear of the offshore and give up plans to set up the E-112 predecessor offshore while at the same time the development of segmented blades for the E-126 facilitated onshore transport and installation logistics.

Power rating *7.58MW* ***Rotor diameter*** *127 m* ***Drivetrain*** *Direct-drive* ***IEC Class*** *IA*

Ming Yang SCD 6.0 MW

Eight years have already passed since the Chinese manufacturer MingYangsignes an official agreement with the German design consultancy Aerodyn in order tobuild its radical downwind two-blade offshore turbine under the license for the Chinese market. However, the project is still to progress to serial production. The problem was that the super compact design (SCD) includes few standard wind-turbine components – some of them had to be made in Germany but the main carrier, the gearbox and generator housing and the rotor hub were cast in China. A prototype with a 140-meter rotor diameter was installed in China in the second half of 2014. Today, Aerodyn, apart from its plans to sell the turbine elsewhere in China, is now working on a 8MW variant with a 168-meter rotor diameter.

Power rating *6.0MW* ***Rotor diameter*** *140 m* ***Drivetrain*** *Medium-speed geared* ***IEC Class*** *II*

Senvion 6.2M152

Senvion introduced a 5MW unit in 2004 under the Repower brand, as it was bought and sold by Suzlon, and continued to develop its offshore turbine. In December 2014 managed to present its 6.15 MW model and a new variant with a rotor diameter of 152 meters which was installed as a prototype. The greater blade length offers a 20% rise in yield at wind speeds of 9.5m/s while the extending operating life is up to 25 years.

Senvion was the first OEM to provide a 5MW-plus offshore turbine but due to economic difficulties of Suzlon its development was slowed down. The German firm as also great plans for a 10MW+ turbine but until today there are no further details.

Power rating *6.15MW* ***Rotor diameter*** *126/152 m* ***Drivetrain*** *High-speed geared* ***IEC Class*** *S*

GE Haliade 6MW

Designed by French company Alstom, the 6MW offshore turbine began producing electricity at its first commercial project, the 30MW Block Island development off the eastern seaboard of the US in late 2016. It was subsumed within GE's portfolio after the US giant acquired Alstom's power and grid business for around € 10 billion in 2015. This specific turbine will power three of the four projects awarded from France's first offshore tender adding up to 1,428 MW or 238 turbines. The same turbine will power the 396 MW Merkur offshore project in Germany's North Sea.

Power rating *6 MW* ***Rotor diameter*** *150.8 m* ***Drivetrain*** *Direct-drive* ***IEC Class*** *IB*

Sinovel SL6000

The domestic development of offshore turbines has unfortunately slowed down due to refusal of China's offshore wind market to grow according to the five-year plan directives. Sinovel showed a 5MW machine some years ago which was upgraded to 6MW in 2011 but was used only for Huaneng Renewables' 102 MW ShangaiLingang demonstration project off China's east coast. The prototype of the 6 MW unit had the same 128-meter rotor diameter as the former 5 MW machine, but this time Sinovel preferred to present a turbine with an extended rotor diameter of 155 meters. Sinovel is also working on a 10 MW turbine and was expected to be presented in prototype form late last year, but its future is not clear due to financial difficulties.

Power rating *6 MW* ***Rotor diameter*** *128 m/155 m* ***Drivetrain*** *High-speed geared* ***IEC Class*** *I*

Dongfang/Hyundai Heavy Industries 5.5MW

Dongfang and Hyundai Heavy Industries (HHI) have both signed license agreements with US-based designer AMSC Windtec Solutions regarding this offshore turbine. Dongfang's prototype, characterizing in-house developed 68-meter rotor blades, was set up and grid-connected at the intertidal Rudong test site in China in summer 2013. On the other hand, Hyundai's was set up onshore on South Korea's Jeju Island in February 2014. AMSC also gives the choice between a long lasting magnet generator and a doubly fed induction generator, too. Until today, both of them haven't got the orders to justify serial manufacture.

Power rating *5.5 MW* ***Rotor diameter*** *140 m* ***Drivetrain*** *High-speed geared* ***IEC Class*** *I*

Adwen AD5-135

Aerodyn actually developed this offshore turbine in the late 1990s, too. In 2004 the first prototype was installed by MultibridGmBH. Thanks to its innovative design, its hybrid drivetrain offering a new solution between direct drive and high-speed geared for a low head mass and high credibility started its operating life with a 116-metre rotor diameter which later extended to 135 meters. Later was rebranded by Adwen, the offshore joint venture between Gamesa and Areva. There are more than 200 Multibrid M5000 turbines that are full operating in European waters with a further 70 of the latest AD-135 model installed at the 350 MW Wikinger project in Germany's Baltic Sea.

Power rating *5 MW* ***Rotor diameter*** *135 m* ***Drivetrain*** *Low-speed geared IEC* ***Class*** *I*

The Entire specifications are included at the Appendices part

Part 2: The Case Study in Greece

19. Overview of Legislation

The **Renewable Energy Directive** lays down an entire policy for the production and promotion of energy from renewable sources in the EU. It demands from EU to satisfy at least 20% of its total energy requirements and at least 10% of their transport fuels that with renewables by the year 2020. According to a **revised Renewable Energy Directive** on 30 November 2016 by the Commission, EU should become a worldwide leader in renewable energy and set the target of at least 27% renewables in the final energy consumption in EU by 2030.

Moreover, it states exactly national renewable energy goals for each country. However, EU countries, in turn, should define **national renewable energy action plans** and measure their success by publishing **progress reports** every two years. Cooperation amongst EU countries (and with countries outside the EU) is promoted by the Directive in the form of statistical transfers of renewable energy, joint renewable energy projects and support schemes. Biofuels and bioliquids assist EU countries in meeting their 10% renewable goal in transport. For this reason, **biofuels sustainability criteria** are specified by the Renewable Energy Directive for all biofuels produced or consumed in the EU to make sure they are produced in a sustainable and environmentally friendly manner. Companies would have the chance to prove their compliance through national systems or so-called **Voluntary schemes** recognized by European Commission.

20. Investing in the Greek Wind Power Sector

Located at the crossroads between East and West, Greece is positioned to play a specifically important role in the area's energy sector. It is also a strong business hub offering access not only to the Balkan countries but also to the EU, Russia and the former East European bloc countries. That is proved by the abundant availability of renewable energy potential (wind, hydro, biomass, geothermal, solar and solar thermal) combined with large-scale infrastructure projects on a ongoing basis including Greece (TAP Gas Pipeline, oil exploration) signify that the country will play a protagonist role in the formality of all of Western Europe's energy mix and will offer significant investment opportunities in the Energy and Energy Saving industries.

According to **the Greek Ministry of Environment and Energy** "The obligation to compile National Action Plan reports to the European Commission on progress in the promotion and use of energy from renewable sources with regard to the target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy in 2020 derives from Directive 2009/28 EC". The availability of financing and the well-promising arrival of a new incentive system have led to a sudden rise in activity in **Greece's wind energy sector,** in spite of the country's difficult economic situation. Greece enjoys by its nature an incredible wind resource with local average wind speeds usually exceeding the 8-10 m/s, specifically in the Aegean Sea islands and on the mountain ridges of the mainland, as well. Greece has made considerable progress in promoting and supporting renewables. Having gained the valuable experience of building the first commercial wind park in Europe in 1983 on the Cycladic island of Kythnos, in 2015 Greece exceeded 2,150 MW of installed wind power capacity; that produced 4.6 TWh at a weighted average price of €89,4 per MWh. For that reason, 10 corporations and their associates are going to invest about 1.5 billion Euros during the next 3 years for the growth of wind-energy facilities with a total capacity of 1.400 MW.

The majority of these projects of strategic importance regarding the renewable energy are being planned by big investors including Terna Energy, EltechAnemos, Protergia, PPC Renewables, Enel, EDF, Iberdrola Rokas, Eren, Elika, and RF Energy, as the Greek Energypress portal stated. The projects can be divided into three important categories. The first regards projects with a total capacity of 500 MW for which applications have already been submitted to LAGIE, the Electricity Market Operator and involves investors who have secured fee-in premiums at a level of EUR 98 per MWH without having to participate in tenders.The second category is about projects at a total of 400 MW in the southern part of Evia, Greece's second largest island. Moreover, an underwater cable linking a substation in Polypotamos on Evian seacoast with another substation in NeaMakri on the coast northeast of Athens.

The third category is about older projects that are characterized by already secured steady tariffs. These agreements have been signed between investors and LAGIE before December 31, 2015 under the condition to be connected to the grid by June, 2018. **The Spanish GamesaCorporacionTecnologia** signed a contract last year to install a wind farm with 12 turbines of 850 kW. It should be mentioned that the wind power capacity on non-interconnected Greek islands was 322.6 MW at the beginning of 2016. In accordance with the calculations made by the European Wind Energy Association (EWEA) in 2015 Greece along with Romania will be the a local wind power leader in the Balkans.

21. The Hellenic Wind Energy Association Joins GWEC

The Hellenic Wind Energy Association (HWEA) has joined the Global Wind Energy Council **(GWEC)** as a new member of its strong influential circle of members that promotes wind energy in the whole world since 2015. The HWEA which is consisted of more than 400 wind energy professionals and companies including scientists, engineers, financiers etc. among others, it does advocacy work with Greek authorities, participates in the social dialogue and organizes events supporting the benefits of wind power in media, as well. The Greek government has already set an ambitious goal to reach 7,500 MW of wind power by 2020.

22. The Greek PPC Renewables is interested in building 12 wind farms on islands

The Greek PPC Renewables (ΔΕΗ Ανανεώσιμες), a subsidiary of the Greek Public Power Corporation (PPC) on August 23, 2017 announced it is looking for partners to construct 12 wind farms in different sites throughout Greece. In this context, the Greek company published three tenders in farms, order to build the wind farms, to operate them and also provide maintenance for a period of 14 years. In accordance with PPC Renewables plans, those 12 wind farms are going to be set up on Greek islands in the Aegean Sea having a total installed power of 31.8 MW.

In the web site of PPC Renewables, there is a reference concerning its strong desire to become a leader in Greece in the field of renewable energy. It has currently 20 wind farms, 17 small hydropower plants and 28 photovoltaic plants with a total installed power of 153 MW.

The Greek PPC Renewables has plans to construct 11 small wind farms with an overall capacity of 24.3 MW on the islands of Marmari, Evia (5.4 MW, Ikaria (0.9MW), Karpathos (0.9MW), Lesvos (2.7MW), Limnos (0.9MW) Samos (1.8MW), Chios (2.7 and 0.9MW), Psarra (1.8MW), Mykonos (1.8MW) and Tinos (4.5MW). The company has also invited offers for the planning, supply, transport, installation an operation of wind farms on the islands of Crete (Sitia) and Tinos and 10 more wind farms until the end of October, 2017.

23. EIB approved a loan for three new wind farms in Greece

In the meanwhile, in July 2017 the European Investment Bank (EIB), has already approved a loan of EUR 24 million for three farm projects in Greece. In addition, the EIB loan has the support of the European Union budget under the European Fund for Strategic Investments (EFSI). This specific loan will be used by the Terna Energy Company to set up and operate 3 wind farms with a total of 18 turbines and a combined installed capacity of 48.6MW outside of Dervenochoria and Tanagra. These wind farms built at altitudes of between 800 metres and 1,000 meters will produce more than 120 GWh of electricity per year.

24. Pavlidis Marble-Granite invested EUR 70 million in 4 wind farms in Greece

Moreover, Greek company Pavlidis Marble-Granite stated that it decided to make an investment of at least EUR 70 million in renewable energy for the time period 2017-2020. This plan is specifically focus on the development of 4 wind farms in Greece with a overall power of 50 MW. As one of the main producers and exporters of white marble worldwide, they are also expecting, among other things, to improve the company's project portfolio.The wind farms will produce electricity in Macedonia and Thrace, especially in Serres, Komotini and Thrace. It should also mentioned that the company's industrial installations have already made use of the energy that comes from their photovoltaic parks with an overall capacity of 5 MW that is equivalent to 12.000.000 m² of forest offering the great advantage to the company not to burden the environment with 6.250 tons of $CO2$.

25. Sustainability Assurance

Assurance is an assessment method that evaluates the quality of a subject matter and contains the communication of the results of this assessment to a group of people. Through the process of **external assurance**, the quality of disclosures and the reporting process is evaluated and recommendations are given to the organization’s management for betterment performance. The assurance statement enhances the trust of the stakeholders toward the assured organization. On the other hand, the external assurance process also gives **valuable insights** to management by reviewing the quality of the materiality assessment, the stakeholder involvement and the overall sustainability management of an organization and also evaluates the way sustainability is integrated the long-term strategy of the assured organization. **In Greece** the practice of sustainability assurance has importantly risen throughout the past years, getting at a historic high for 2013 at 45%. In addition, the reduced percentage of 2012, in comparison with 2011 and 2013, might be attributed to the mergers and Group level reports as we have already discussed.

The usage of an assurance standard supplies a consistent methodology in assessing sustainability report and raises the confidence of the final user on the assurance work performed. The most widely known used assurance standards on world scale for sustainability assurance are ISAE 3000 and AA1000AS. The International Standard on Assurance Engagements 3000 **(ISAE 3000)** issued by the International Auditing and Assurance Standards Board **(IAASB)** of the International Federation of Accountants **(IFAC)**, is an assurance standard that audit firms are eligible to use. It includes a suitable subject matter, appropriate criteria, adequate suitable evidence and a written assurance report. The **AA1000Assurance Standard** was created by AccountAbility, a global organization in London, UK. It can be used only by licensed assurance providers and its goal is to give assurance not only of the reliability of information but also to assess the nature and extent of an organization's adhesion to the AccounAbility Principles while evaluating the total integration of sustainability in the whole organization.

Concerning the assurance standards in Greece**,** it is revealed that the number of reports assured without the use of any assurance standard has increased a lot, a fact that put the assurance process and reliability of the assurance provider's conclusions at risk. Assurance standards should be guiding every professional assurance statement and be publicly available. Even if ISAE300 and AA100AS are the most well-known used standards in **Greece**, based on the relevant world trend, however, a much dangerous 18% of assurance statements following other protocols that most of the times are not publicly available and even worst a 37% following no assurance standard at all.According to this desk research regarding Greek reporters, 36% of assurance statements found in 2013 reference year reports to be provided by audit firms, 45% by certification bodies and 18% by other professional providers. Of course this is not coherent with recent world trends where based on global research audit firms lead the sustainability assurance market mainly due to high quality audits connected to the usage of world international assurance standards for non-financial information. "Audit firms generally provide a higher quality of assurance in comparison with other assurance providers on aspects related to reporting format and procedures used" (Perego,P. 2009).

26. Looking ahead

The rising expectations of stakeholders and investors for non-financial assessment of companies have given much importance to the issue of how a firm creates value through its core business in the short and long term and also how this is solved by sustainability or integrated reporting. Reporting allows both the company and its stakeholders to assess its sustainability business practices and take the decision how these are adding to its economic performance. In accordance with a recent EY publication, 94% of respondents believe the valuation of sustainability have the strength to alter an organization, moving sustainability into the boardroom.

Furthermore, new reporting guidelines, both in Europe and the U.S. greatly concentrate on the issue of materiality which conforms to investor preference for reporting on what truly matters. Towards this direction, an important challenge for reporters is to recognize their impacts within their corporate limits and within their value chain and to become capable of demonstrating this in their reports.

The future of sustainability reporting in Greece is uncertain, as it still struggles to develop from a communication to a strategy tool and to depict its value to the boardrooms in the middle of an economic and political environment in the opposite direction. Although the amount of Greek sustainability reports is very restricted and principally ascribed to big organizations, quality is actually improving. This happens due to an increased application of international reporting and management standards and more firms apply enhanced approaches to ascertaining report content, invest in stakeholder engagement and choose to have their reports externally assured.

The European Commission Directive 2014/95/EU on revelation on non-financial and variety in the information by certain large undertakings and groups which amends the Accounting Directive 2013/34/EU entered into force on 6 December 2014. In accordance with the European Commission's official website on non-financial reporting, EU Member States have two years to transpose it into national legislation. In this context, the European Commission is organizing informal transposition workshops to assist national authorities. The first transposition workshop took place in Brussels on 24 March 2015. Based on the same source, "the session proved to be a very helpful forum for sharing the state-of-play of the transposition across Member States, and discussing practical implementation issues. The next transposition workshop is planned for September 2015".

While many Member States have already begun the transposition process and have tangible implementation plans, the questions for Greece remain at a more basic level. The value of non-financial reporting in a market characterized by instability and stagnation of growth raises many questions. Greek companies seem not to have understood that their corporate sustainability is interlinked with extra financial features. Are they able to capitalize on the value of reporting and go beyond to more sustainable shared-value business models? Time will show if treating reporting as mainly a communication tool is a big Greek failure or not.

27. Market Analysis of the Offshore Industry

Competitive approach for strategy development is a to-down approach as for developing a strategy and is founded on understanding the surrounding environment of the company and the fundamental principles of free market and trade.

It actually describes the competition and rivalry among the existing competitors, threat of new entrants, threat of substitute products and services, bargaining power of buyers and bargaining power of suppliers. The above forces are included in the **Porter's Five Forces** model of analysis. Nevertheless, competitive strategy approach and Porter's five forces do not really reflect customers needs or does it to a very limited extent. The customer's needs are translated into the strategy by rivalry among existing companies, threat of substitutes and bargaining power of buyers. The customer interest as input to strategy is in fact assimilated circuitously.

Due to the nature of competitive strategy theory the research is mostly relied on secondary data. The core of the research is **data** that comes from surveys and outlooks that have been published by international energy organizations. These are World Energy Council "World Energy Scenarios: Composing energy futures to 2050", published in 2013, Global Wind Energy Council "Global Wind Report – Annual Market Update 2014" and European Wind Energy Council "Wind Energy Scenarios 2020", published in 2014. As the research is relied on public sources and data, the ethical issues concerning processing and publishing the data and providing confidentiality to the sources are not expected to rise during the research.

A constrain to the research is accessibility to the information. The working documents of strategy development units at wind turbine manufacturers is classified information and therefore, limiting the research. Thus, the research is based on public information such as information on annual reports and press releases of listed companies, information on strategies published on company web pages as well as market outlook analysis. Generally speaking, wind is the most competitive renewable energy source (WEC 2013). Finding ways to enter this industry increases competition among wind turbine manufacturers. Technological improvements of wind turbines that are driven by increasing competition can raise renewable energy's competitiveness over conventional, fossil-fuel based energy technologies. This has an impact on raising energy sector sustainability by finding fossil fuels usage and negative effects that are caused due to it. The ethical aspects of this thesis are connected with making renewable energy more accessible to larger quantities of companies and people. This includes ethical views that are set inside to be transformed from fossil fuels into renewable energy that has a significant impact specifically on industries that do consume energy in large quantities. They are also in the position to provide energy to regions and people in the developing countries who currently do not have access to electricity.

In this section, the data on wind turbines market and strategies of major companies operating on the market are displayed, as well. The outlook is presented in two time horizons: general level energy market outlook is given on time horizon 2050 and detailed level wind turbine market outlook that is also provided on time horizon 2020.

Horizon 2020 outlook is displayed by the following regions: Europe, Asia, North-America, Latin-America, Africa, Middle East and Pacific. The present outlook indicates the main trends as well as main drivers and dangers behind the forecaster trends.

This section analyzes main competitors and their strategies, as well which are categorized in accordance with Porter's generic type’s strategies. European wind turbine manufacturers that belong to Global Top 10 are also reviewed in total 6 companies. Moreover, a Finnish company Mervento, which has already completed its first prototype and at present is searching for its first customers, is reviewed, too.

27.1 *Long-term energy market perspective – 2050*

World Energy Council (WEC) foretells that the energy landscape in 2050 will look pretty different compared to how it looks today (WEC 2013). WEC actually published the outlook in two parallel scenarios. The first is called Jazz and it focuses on energy equity accomplishing individual access and affordability of energy through economic growth as priority. The second that is called Symphony is concentrated on achieving environmental sustainability via international policies, practices and agreements. In addition, the world population will be raised from 7 billion to about 9 billion (8,7 – Jazz and 9,4 - Symphony). The GDP per capita will increase from 9000 US$ in 2010 to around 20000 US$ in 2050.

According to the outlook, the energy demand will increase and immense pressure is put on energy system to be developed. WEC also gives estimation that by 2050, the total primary energy supply and consumption will have been increased globally to 244 PWh based on Jazz scenario and 193 PWh on Symphony scenario. In 2010 the corresponding number was 152 PWh which is equivalent to increase of 61% or 27% respectively. Between 1990 and 2010the total primary energy consumption increased roughly by 45% and it is expected that energy consumption will rise at much lower rate than in previous decades. The outlook for future energy mix shows that the growth rates will be at the highest level concerning renewable energy sources. Nevertheless, fossil fuels such as coal, oil and gas will remain dominant in 2050 as well. The share of fossil fuels will be 77% in Jazz scenario and 59% in Symphony scenario compared to 79% in 2010.

By 2050, economic growth will have shifted from developed countries to developing countries and transition economies, especially in Asia. Almost half of economic growth will occur in Central and South Asia, East Asia, Southeast Asia and Pacific. Based on WEC Jazz, the share of Asia as for total primary energy consumption will increase from 40% in 2010 to 48%; in WEC Symphony, respectively 45%.

By 2050, Europe and North America (including Mexico) will have made up about 30% of total global primary energy consumption in Jazz and 31% in Symphony (2010: 44%). Africa, including the Middle East, will account for 15% in Jazz and 16% in Symphony (2010: 11%) while Latin America and The Caribbean (LAC) 8% in Jazz and 7% in Symphony (2010: 5%).

27.2 *Mid-term wind turbines market perspective - 2020*

By 2020, WEC predicts that total installed capacity of wind power will have raised to 404 GW (Jazz scenario) or 667 GW (Symphony scenario) with an outlook for 2030 respectively 621 GW and 1059 GW. Revenue generated per MW of wind power capacity that produced is about 1.5 million Euros (15 billion Euros per GW). The market is dominated by Asia and followed by Europe (GWEC 2014).The year 2014 was great for wind turbine manufacturing industry; there was 44% annual market growth and more than 51 GW installed capacity while 23 GW (45%) of that was installed in China. The emerging markets maintain a strong position in Africa, Latin America and Asia while OECD markets continue to make steady progress as a whole.

In OECD countries, the development of wind power is driven by government policies that come also from ethical concerns regarding the environment and climate. Denmark has been the leader while in Germany wind power has reached double-digit penetration rates. The traditional government policy is about to implement a feed-in tariff structure, but the need to move towards more market makes necessary approaches such as traded green certificates. In non-OECD countries the wind turbine development is defined by economics, energy security and price stability. Especially in China there is the need for emergency procedure to address the smog that is made due to the urban industrialized areas. It’s time for markets to take the initiative to make sustainable growth.

European Commission's Renewable Energy directive (GWEC 2014) is the key driver for European markets. The directive states that by 2020,20% of Member States’ final energy consumption must derive from renewable sources (European Commission 2009). Furthermore, supported by the national action plans, European targets will have to be resulted in installing new wind capacity of cumulative installations of 75 GW (GWEC 2014). European Wind Energy Association central scenario predicts that installed capacity increases by 64% compared to 2013 192.5 GW which leads to the production of 442 TWh of electricity meeting 14.9% of Europe's total electricity consumption in 2020. The low scenario foretells onshore installations of 165.6 GW (increase by 41% compared to 2013) and offshore installations of 19.5 GW. The high scenario predicts respectively 217 GW (84.9% compared to 2013) and 28 GW (EWEA 2014).

The major factors that affect market developments apart from economic reality are stability of regulatory market and frameworks for wind energy. This has an impact on wind power investment plants, new orders and investment decisions that have already taken across the Europe. Retroactive and retrospective changes to regulatory market frameworks have had a negative impact on wind energy sector and it carries on being the major risk in the future (EWEA 2014).

On the other hand, in Europe, Germany's performance will likely remain strong via the period mostly because of the offshore segment that is developing at a fast pace while re-powering the onshore wind parks. UK market is foretold to be stalled whereas is waiting for the outcome of the elections that would probably offer some stability and positive support to the sector. Sweden and France are considered to be strong enough to continue their good performance. An increase in growth is also predicted as for Poland and Turkey which is predicted to become a major market. The offshore market seems to be much healthier compared to how it was before 2014. More realistic targets have been set as there is a greater diversity of suppliers of next generation 5MW accompanied by more powerful offshore wind turbines (GWEC 2014). Offshore installations are predicted to reach almost 23.5 GW (EWEA 2014). Among the factors that could change the 2030 outlook are the energy demand, overall state of the countries’ economies, pressure on public spending and also agreements on EU post 2020 targets. Last but not least, the potential impact of the 2015 COP climate negotiations in Paris is also significant for the whole progress, too. (EWEA 2014).

27.3 *Competitors*

Strategies of European-based wind turbine manufacturers that belong to global Top 10 are reviewed and analyzed to classify company's strategies in accordance with Porter's generic types. The analysis does not predict one-to-one matches of companies’ strategies and Porter's classifications but it is concentrated on finding main characteristics of companies’ strategies.

28. Choosing the location: Methodology

The locations which are proposed for the infrastructure are illustrated on the following WWF’s map and located on the **North Aegean Sea, North Evoia and North Aegean Sea Islands.** To decide the appropriate location, multiple criteria have been used.

29. The Morphology of Greece

During the last 50 – 70 million years, the presence of Mediterranean Sea has resulted in a tremendous interaction and complicating geodynamical processes on Greek territory.

Analytically, the Ionian and Levantine Sea are the remains of the old Tethys Ocean, which is separated in Greek, Cypriot and Calabrian arcs. The Aegean Archipelagos is the outcome of the expansion of the Greek arc throughout the years.

The bathymetry and the whole forming of Greek mainland, islands and marine topography are resulted from three geotectonic processes that are still active during the last 10 – 15 years: 1) The Middle to Late Miocene post-orogenic extension and disinterment of the alpine mountain belts, 2) The migration of the North Anatolian Fault (NAF) westwards into the north Aegean Sea in Late Miocene–Early Pliocene and the westward motion of the Anatolian continental block and 3) Below the Aegean microplate the northward subduction of the eastern Mediterranean crust that resulted in stretching of the latter in a north-northeast –south-southwest direction.

Due to the geologic history of the eastern Mediterranean and the most recent geodynamic processes and movements, **the sea-floor of the Hellenic Seas is featured by a very complicated morphology**. Behind the southwards migrating orogenic arc, the Aegean Sea has been taken the form of a back-arc basin between continental Hellas and Asia Minor, and hosts the active volcanic arc.A specific formation to the southern limit of the Aegean Sea toward the eastern Mediterranean and the Ionian Sea is given by the southernmost Aegean islands (Kythira, Kriti,Karpathos, Rodos). Surrounded by the southernmost Hellenic territories in the south, the Ionian Sea is found west of continental Hellas and the Hellenic Trench, hosts the deepest basins of the Mediterranean Sea. Their sea floor relief is very irregular and under the control of strong active faulting. Most of the gulfs are of tectonic origin and analyze the Aegean and the Ionian Seas coastline. Three distinct areas that are characterized by various morphological features and geotectonic regimes divide the Aegean Sea into the northern, the central and the southern part.

30. North Aegean

North Aegean Shelf: The northern margin of the Trough is made up of shallow platforms that are analyzed in NW-SE trending wind gulfs, like the Thermaikos and Strymonikos gulfs. Between the Strymonikos and Saros gulfs, a wide shallow platform with the Thasos and Samothraki Islands on it is extended. The North Aegean Shelf depicts the offshore continuation of the alluvial planes of northern Hellas and east Thraki. Most of these planes have been made in Upper Miocene Lower Pliocene as continental basins filled up by lacustrine and fluvial Plio – Pleistocene deposits (LYBERIS, 1984) are also being drained by rivers that feed the shelf and the trough with terrigenous clastic material.

North Aegean Trough: The prevailing morphological feature in the **N**orthern **A**egean **S**ea is the homonymous **T**rough (**NAT**), which has grown along the trace of the **N**orthern **A**natolian **F**ault (**NAF**).

The North Aegean Trough consists of a series of three main elongated depressions (sunken areas) that are separated from each other by morphological highs. The eastern depression is a narrow, N70E striking and up to 1400 m deep basin that extends from Limnos Island to the Guld of Saros. The second depression with an average depth of 1200m is located to the SE of the Chalkidiki Peninsula and points out a progressive widening and shift of the Trough axis to N50E.

The western depression corresponds to the 1500 m deep and wide Sporades Basin. Sedimentation in the North Aegean Trough consists mainly of hemipelagic mud, turbidites and gravity driven deposits that come firstly from the outer shelf and upper slopes of the trough.

Sporades-Limnos Plateau: Steep fault scraps delineate the southern slopes of the North Aegean Trough which depict the sharp contact to the 100-300 m shallow platform that is extending between the Sporades islands in the west and the Limnos an Imvros islands in the east.

Various basins: Secondary strike slip faults that are running parallel to the North Anatolian Fault together with normal faults have the responsibility for the formation of narrow but deep small basins in the region between the North Aegean Trough and the Central Aegean Plateau (MASCLE & MARTIN, 1990). The 1000 m deep Skopelos Basin, the 800 m deep Kymi Basin, the 800 m deep S. Skyros Basin, the 1000 m deep N.Skyros Basin and the 800 m deep Psara Basin depict remote morphological depressions separated from each other by 200-400 m shallow platforms. Before the shallow Central Aegean Plateau, the 800-1000 m deep Ikaria Basin constitutes the southernmost deep the shallow Central Aegean Plateau. All these basins are of tectonic origin due to the fact that active faulting that controls their subsidence and are also surrounded by steep slopes.

31. Central Aegean

The Central Aegean Plateau (Kyklades Plateau) depicts a shallow platform of about 200 m mean depth that forms the morphological link between the Attiki Peninsula and the S. Evvoia Island to the west and the Menderes region in Asia Minor to the east. The theoretical line passing over Andros, Tinos, Mykonos, Ikaria and Samos islands constitutes the northern limit of the shallow plateau. The southern limit of the Central Aegean Plateau concurs with the Volcanic Arc where Nisyros, Santorini, Milos, Poros and Aigina Islands with smaller islets and submarine volcanic centers belong to. The curved shape of the Central Aegean shallow plateau, the result of stretching of the Aegean microplate in a NNE-SSW direction (LE PICHON & ANGELIER, 1981; MASCLE & MARTIN, 1990) follows the general shape of the Hellenic Arc and Trench System. The low seismic potential and the weak neotectonic activity and faulting of the area is reflected in the gentle submarine morphology of the central Aegean. Biogenic sedimentation is predominant in the shallow platforms between the numerous islands and islets, too.

32. South Aegean

A series of deep lengthened basins are allocated between the Volcanic Arc to the north and the Island Arc to the south. The south Aegean basins extend from the Argolikos Gulf, off the eastern Peloponnisos, over the Cretan Sea between Kriti and Santorini Islands while continue to the Sea of Karpathos west of Karpathos Island.
Furthermore, the greatest depths of the Aegean Sea are to be here. The N-S elongated Karpathos Basin is 2500 m deep and is bordered by a steep faulted slope toward Karpathos Island. The Karpathos Basin is separated from the 2200 m deep Kamilonisi Basin by a 1300 m deep shallow ridge. Kamilonisi Basin is placed between the northern coast of eastern Kriti and the theKamilonisi Islet. Next to this and north of central Kriti the 1800 m deep Irakleio Basin does occupy the central part of the southern Aegean Sea. Further to the west, a shallower but long and narrow basin follows the shallow ridge that actually connects western Kriti with the Antikythira and Kythira Islands and the eastern Peloponnisos. Active over the region throughout the last 5 million years, the formation and distribution of the Deep South Aegean basins is the result indeed of the geotectonic regime. However, the tectonic and seismic activity in the northern Aegean is currently much higher regarding those in the southern Aegean. Tectonic activity has migrated southwards and influences the Island Arc with faulting which has the responsibility for uplift or subsidence of successive areas along the arc. The formation of relatively shallow characteristics west and east of Kriti is the result of the tectonic fragmentation of the Island Arc which allows water exchange between the Aegean Sea and the east Mediterranean.

33. Ionian Sea

In the Ionian Sea there are two different parts that may be recognized: the northern and the southern one with the existence of the boundary between them made them to be marked by the Kefallonia strike-slip fault. The northern part can be seen as the southward extension of the Adriatic Sea. The northern Ionian Sea is feauted by an extensive shelf, with Kerkyra Island being part of it and connected to a relatively flat basin by a steep slope. The sea –floor morphology coincides with the high seismicity of the region and alters dramatically in the southern part of the Ionian Sea. Normal active faults are responsible for the formation of deep gulfs, such as the Messiniakos and Lakonikos gulfs and valleys. The regional tectonics and fault movements control the sedimentation in these places. Turbidites and gravity driven deposits give a form to the bulk sedimentary infill.The shelf and the slope off the Ionian island and the Peloponnisos are dissected by deeply eroded submarine canyons which terminated down-slope in small deep remote basins at depths over 4000 m. The deepest basin (Vavilov Deep) in the Mediterranean Sea is located in this area 30 miles of the SW coast of the Peloponnisos and is over 5100 m deep.

34. The Offshore wind farm of the Thesis

The contractor of the offshore wind farm is the Wind Technology S.A, a company with a large portfolio of renewable energy Investments across Greek mainland. The board of this company decided to invest in the fast- moving sector of offshore wind farms/technology. On March of 2016 they contacted and order the Green Advisors LTD, a consulting and Engineering Procurement Company (EPC) in order to decide if such an installation in Greece is feasible and profitable. The Green Advisors company with a specialized team of Engineers, Risk Analysts and Economists for six months occupied with the realization of this feasibility report. Afterwards, at the headquarters of Wind Technology S.A, a team of Green Advisors S.A, with head of the team Mrs.N.Laurence, presented the deductions and if this investment is really profitable for the company, analyzing basic financial indicators. Next pages will show if the investors undertake the decision to support the first offshore wind farm in Greece.

35. Locating offshore wind farm

A large number of parameters must be evaluated to choose the appropriate location for an offshore wind farm.

Figure 14: Location of the farm and 12km distance from the Mainland

The first one is the velocity of the wind that is evaluated with a wind rose diagram which has been analyzed on previous pages. The most appropriate velocity is an average value of 7m/sec and parameter 2 for Rayleigh distribution. If the number is small enough, the distribution is more homogeneous and efficient. According to WWF´s wind rose maps, the north part of Aegean Sea and Aegean Sea depict these characteristics. The parameter value is almost 2 and the velocity is equal to 7m/sec. Furthermore, the morphology of the Aegean Sea and Aegean Sea, according to WWF, is the best choice for wind farm foundations. A map of the designated regions is illustrated at the Appendices. We should keep in mind the above parameters because the most effective location is the Aegean Sea due to the appropriate wind velocity and morphology. Moreover, the transmission lines of 400kV requirements for the wind farm are available and the cost for submarine cables has been minimized in comparison with the other locations. So, the wind farm will be located 12km far from the land, in order to avoid the visual impact according to the EIA. The following figure depicts an Auto-cad configuration of the wind farm.

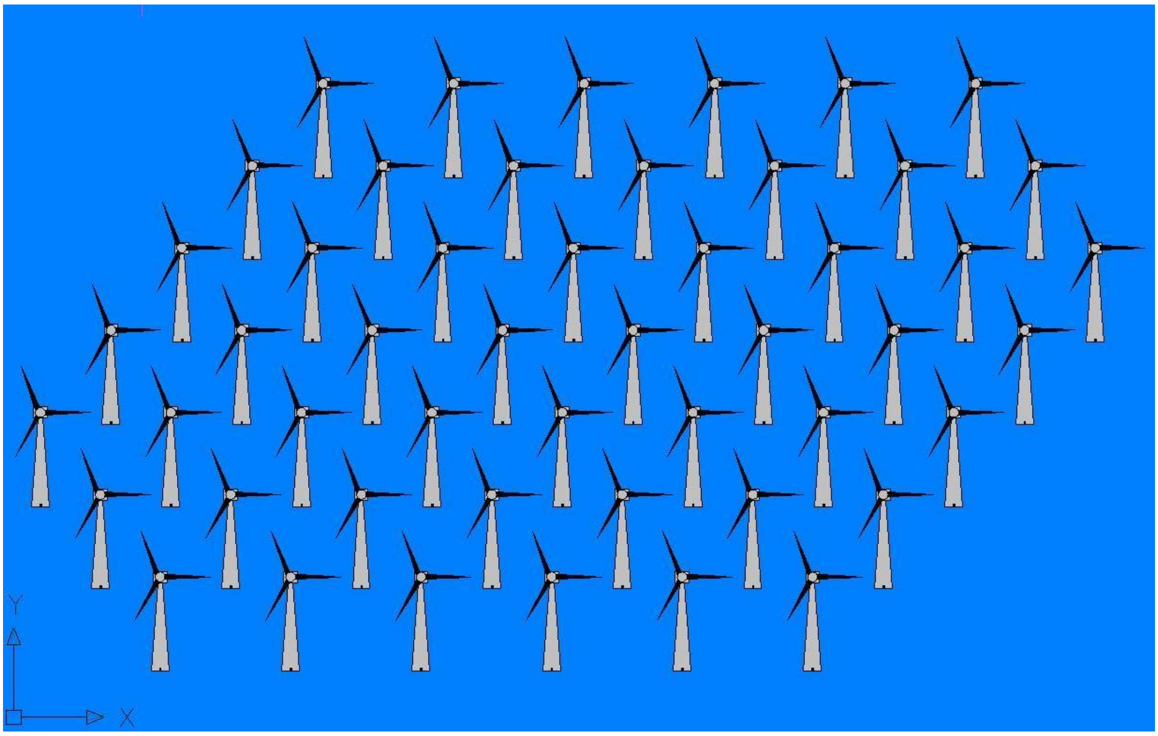


Figure 15: Auto-cad Layout of the Wind Plant

36. The Grid System of Greece

This infrastructure will be connected with the 400 kW transmission lines of Evoia. The following data has been used from the site of ADMHE which is the authority to anything that has to do with the installation, management and maintenance of transmission lines in Greece.

The Hellenic Electricity Transmission System is made up of three, double-circuit 400 kV lines that transmit electricity principally from Western Macedonia where 70% of the country's generation capacity is located to the major electricity demand centers of Central and Southern Greece where 65 % of the country's electricity demand is found. The Hellenic Electricity Transmission System comprises additional 400 kV and 150 kV lines in addition to 150 kV submarine cables that interconnect Andros with the Western Greece islands, Corfu, Lefkada, Cephaloniia and Zakynthos and a 66 kV submarine cable connecting Corfu with Igoumenitsa. As of 30th June 2012, the Hellenic Electricity Transmission System was consisted of 11.303 km of Transmission lines as depicted on the table below.

A map of the whole Transmission line system of Greece is located in the appendices.

37. Power Yield

The entire offshore wind farm is consisted of 50 wind turbines of 8 MW each. The power yield of the 400MW wind farm has been estimated with the help of the Wind Farm performance program.

Table 1: The results from the Wind Farm Performance Program

Location	North Aegean Sea
Wind Power Plant*	400MW
Rotor Diameter	115m
Wind Speed	7m/sec
Maximum Performance Coefficient	0.476
Mean Wind Power Yield**	4816270GWh/annually
Average Households	150.000

*8MW (each Turbine) × 50= 400MW (1) **

*Outcome of the program***

To estimate the power yield of an offshore wind farm it is significant to co-estimate the parameters of the site layout, such as wind speed, mean air density and, parameters of the wind farm, such as the nominal power etc. The following figure illustrates the parameters and the power yield of the 400MW offshore wind park, which is transmitted to the Grid annually. The following table depicts the characteristics of the offshore wind farm. Furthermore, a screen shot from the program is illustrated at the Appendices.

38. Submarine cables of the offshore wind farm

The use of high efficiency and protection submarine cables are of greatly importance for the power supply. The AC to DC conversion and the transmission is the building block of an offshore wind farm. These cables should be extremely reliable and have depth/water resistance. Submarine power cables transmit AC voltage to higher AC and afterwards to higher DC voltage.

Submarine cables can be anything from 70mm to, exceeding, the 210mm diameter for the transmission. The criteria to choose the appropriate submarine power cable are the cable rooting, the bathometry, the morphology of the underwater ground, Grid synchronization and the power yield. For a less than 80km distance from the land, the appropriate sorts of cables are thesubmarine ones which are really economical, especially the AC part. Distances that exceed the 80km boundary should enable an expertise DC technology, which drastically increases the entire cable cost. The scope of this thesis enables submarine cables that cover a 12km-distance from the land.

Referring to the AC part, the typical one is a three-phase cable with three core formation or three different cables stuck together. The DC part can be either mono-polar or BI-polar. It is really essential to examine the case of each one, which will not be covered by the aim of this thesis. Generally, DC cables are consisted of two conductors, mainly with co-axial formation. The first HVDC submarine cable has been used to interconnect a 98km distance from Gotland Island to Swedish main territory and has a capacity of 20 MW.This infrastructure has been installed circa 1954. In the submarine cable market, there are big players like ABB, DONG, KIS-ORCA, which have covered more than 80 offshore wind farms around North Europe with their submarine cables and with a capacity that exceeds the 60GW. The characteristics of the cables and the safety protection of the cables are included at the Appendices´ part.

39. PEFLEX protection cable system for wind

The protection scheme has been emerged due to the fact that offshore wind farm is a really renewable moving sector. For this reason, new technologies and remedies get involved to prevent fatal collapses and injuries.

The PEFLEX Scheme is the most recent protection technology for the submarine power cables. This method protects from freespan arrays and export cables to/from offshore wind farm. Rigid interlocking polyurethane half sections are combined with elastomeric elements to form the PEFLEX Scheme. It is a patented technology and covers the full length of the three-phase cables. The cable enters a tip and then rooted inside a J-Tube and J- Tubeless connections, allocated at the monopiles of the substations, both submarine and onshore and the towers of the wind turbines.

The pros of this process are shown above:

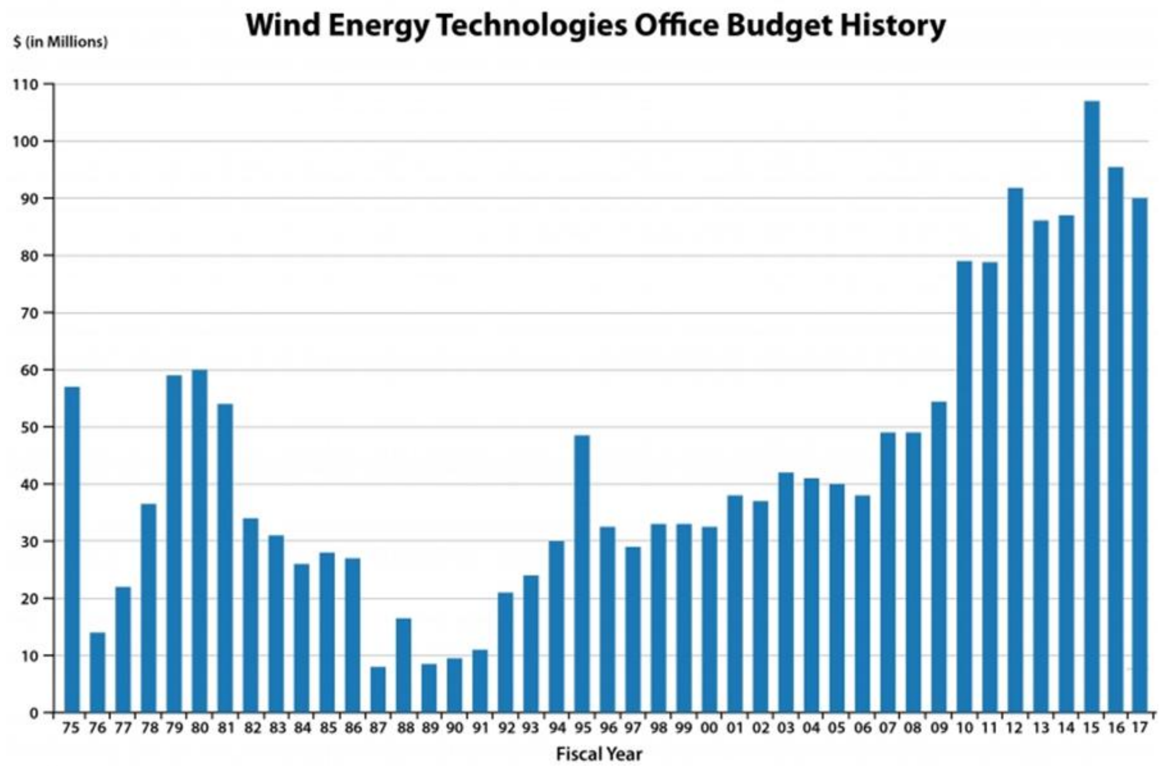
- Very innovative and up-to-date technology.
- Prevent from arcs and fatal collapses.
- Global supply and O& M network.
- Highly reliable.
- 20 years life expectancy.
- Turn-key solution.
- Customized depending on the parameters of each project.
- Continuously improving methods.

40. Budgeting of an offshore wind farm

Before investing on a budget, it is necessary to conduct a survey on the market and gain insight into similar projects around the world. These kind of large scale energy investments also receive budgets from governmental schemes, such as the U.S Department of Energy which has penetrated in this field in the last 20 years. Since 2008, the U.S Department of Energy has invested more than $731 million on offshore wind farms around the U.S marine territory.

The following Table includes the exact amounts of each year since 2008. In Europe, the European Bank for Investments can afford the realization of this kind of installations. Nevertheless, the detailed process and methods which should be followed will take more than a decade. The graph below depicts the amounts the Department of U.S Energy spent since 2008.

A large amount of renewable investments have waited for the green light to start for more than ten years, especially in Greece. Another option is the implementation of Operational Programs that are co-financed by both the European Structural and Investment Funds and the Partnership Agreement (PA), known as (ESPA).



Fiscal Year	Funding
2008	$49.0M
2009	$54.4M
2010	$79.0M
2011	$78.8M
2012	$91.8M
2013	$86.1M
2014	$87.0M
2015	$107.0M
2016	$95.45M
2017	$90.0M

Figure 16: The Supporting budgeting since 2008 (Wind Energy Technology Office)

But this option is not considered as a real choice for this project, due to the large amount that is required. According to Prof. P. Pataraya of University of Aberdeen, it is wise to follow a simple process to find out the way for an offshore wind farm budget planning. The first step is comparison and contrast of offshore wind farms with similar or familiar equipment and power yield. The next step is the comparison of expenditures and finding ways to minimize surplus expenses. The last step is the presentation of the theoretical capital budgeting of an offshore wind farm assessing the pros and cons of each available option. This approach shows some assumptions such as the scale of the farm, the feed-in tariffs, and the contracts from EPC and O& M companies and the European Obligations for these types of infrastructures.

Then it runs a model to find out the NPV value of each case and afterwards chooses the most suitable. The exact approach is contained at the Appendices section.Another approach is the scheme of private capitals and bank lending. The most familiar in European investments is a scheme covered by 30% from investors and 70% is covered by budgeting loans. This approach has been chosen based on different rates which have been examined in the sensitivity analysis section.

41. Financial Analysis

The main purpose of a feasibility report is to present the project parameters, assess potential solutions to the business problem, need or opportunity and determine which of these are viable for further analysis, given certain constraints. These constraints could be financial, social, practical, technical, environmental or any other things that could make it impossible or impractical for a solution to be implemented.

This specific part of thesis is really very crucial due to the fact that it will enlighten the reader to ascertain if this large scale offshore wind farm project is viable in financial terms and criteria. For that reason, it illustrates criteria, methods and deduction that will defend or not the sustainability of the investment.

41.1 *Literature Review*

To evaluate an investment is pretty difficult as it involves the terms of risk and uncertainty. This particular analysis focuses on tools that should be adopted to decrease costs, on finding the most flexible and economic methods for production, using right persons and tools depending on the circumstances, with a view to make the investment offer a positive income to investors. It is also of crucial importance to use methods that enable forecasts for returns and expenses, budgeting approaches, the cash flow analysis and capital budgeting decision methods, too. The above processes will be analyzed in further details to form the final deduction of the project.

41.2 *Financial Analysis Explanation*

Financial analysis is the meticulous process of evaluating businesses, projects, budgets and other finance-related entities to determine their performance and suitability but mainly to analyze whether an entity is stable, solvent, liquid or profitable adequate to warrant a monetary investment. When investigating the actions of a specific company, a financial analyst conducts analysis by primarily focusing on the income statement, balance sheet and cash flow statement. Generally speaking, financial analysis is used to evaluate economic trends, set financial policy, build long-term plans for business activity and identify projects or companies for investment. This is done through the synthesis of financial numbers and data.

One of the most common ways to analyze financial data is to calculate ratios from the given data to compare against those of other companies or against the company's own historical performance. For instance, return on assets (**ROA**) is a common ration used to define how much efficient a company is at using its assets to generate earnings and is displayed as a percentage. This ration could be calculated for several similar companies and compared as a part of a larger analysis.

Financial analysis can also be conducted in both corporate finance and investment finance settings. Regarding corporate finance, the analysis is conducted internally by using such ratios as net present value (**NVP**) and internal rate of return (**IRR**) to find projects worth executing. A key area of corporate financial analysis involves extrapolating a company's past performance, such as gross revenue or profit margin, into an estimate of the company's future performance. This allows business to forecast budgets and take decisions on past trends, such as inventory levels.

41.3 *Investment Analysis*

Investment finance is a broad term that contains analyzing past returns to make predictions, as safe as possible, concerning future returns, selecting the kind of investment means that is best as for an investor's needs or evaluating securities, such as stocks and bonds for valuation and investor peculiarity.

When making investment decisions, analysts can either conduct a top-down or bottom-up investment approach. A top-down approach first looks for macroeconomic opportunities, like high-performing sectors, and then investigates thoroughly to find out the best companies within that sector. On the other hand, a bottom-up approach pays attention to a specific company and carries out similar ratio analysis to corporate financial analysis, looking at past performance and expected future performance as investment indicators. There are two types of financial analysis: technical analysis and fundamental analysis. The former looks at quantitative chart, like moving averages, while the latte uses ratios such as a company's earnings per share (**EPS**).

Investment analysis can help define how an investment is probably to perform and how appropriate it is for an investor, as it plays a great role for any sound portfolio management strategy. In case investors are not capable of doing their own investment analysis, they could seek professional advice either from a financial advisor or some other financial professional. It can also contain evaluating past investment decisions in relation to the thought process that went into making them, how the decision influenced a portfolio's performance and how mistakes can be examined and corrected. Entry price, expected time horizon and reasons for taking the decision at the specific time are key factors in investment analysis.

42. Performing Investment Analysis

When carrying out an investment analysis of a mutual fund, an investor looks at factors such as how the fund has performed comparing to its benchmark. The investor can also compare similar funds to expense ratio, management stability, the fund's performance, sector weighting, style and asset allocation, too. In case of analyzing an investment, investment goals should always be meticulously considered; one size does not always fit all and highest returns in spite of risk are not always the goal.

42.1 *Types of Investment Analysis*

Investors can make usage of a bottom-up investment analysis approach or top-down approach if they are taking investment decisions. Bottom-up investment analysis involves analyzing individual stocks for their merits, such as valuation, management competence, pricing power and other unique features of the stock and company. It does not concentrate on economic cycles or market cycles as for capital allocation decisions but intend to find the best companies and stocks without considering of economic, market or specific industry macro trends. Basically, bottom-up investing takes more of a microeconomic approach to investing instead of a macroeconomic one as it is a hallmark of top-down investment analysis. Top-down investment analysis gives more emphasis to economic, market and industrial trends prior to taking a more granular investment decision in order to allocate capital to particular companies. In case, for instance, of evaluating industries, if an investor finds out that financials will probably perform better in comparison with industrials, he decides his investment portfolio will be overweight while underweight industrials and afterwards, he carries on finding the best stocks in each sector.

On the other hand, a bottom-up investor may have found that an industrial company mad for a persuasive investment and assigned an important amount of capital to it even if the outlook for its broader industry was negative. Other investment analyses contain fundamental analysis and technical analysis, too. In case of fundamental analysis, the financial health of companies and economic outlooks are under great consideration and evaluation while technical analysis gives emphasis to patterns of stock prices and statistical parameters. The cash flow statement indicates how much cash comes in and goes out of the company over the quarter or the year. At first sight, it seems that the income statement records financial performance over a specified period of time. However, there is a big difference between the two.

What makes out the two of them is accrual accounting that is found on the income statement. As for accrual accounting, companies should keep a record of revenues and expenses when transactions take place, and not when cash is exchanged. Simultaneously, the income statement often contains non-cash revenues or expenses which statement of cash flows does not include at all.

For instance, when the income statement indicates net income of $10 does not mean that cash on the balance sheet will rise by $10. Whilst when the bottom of ht cash flow statement reads $10 net cash inflow, that is exactly what it means. The company has got $10 more in cash that at the end of the last financial period. You may think of net cash that come from operations as the company's 'true' cash profit. The statement of cash flows is of crucial importance to understand a company's fundamentals due to the fact that it displays how much actual cash a company has generated. It shows how the company is able to pay for its operations and future growth. In fact, one of the most significant characteristics you should seek in a possible investment is the company's ability to generate cash. If a company indicates a profit on the income statement it does not mean that it cannot get into trouble later due to the insufficient cash flows. A close examination of the cash flow statement could give investors the opportunity to have a better sense of how the company will fare (well or badly).

43. Three Sections of the Cash Flow Statement

Companies generate and consume cash in many different ways so that the cash flow statement is divided into three sections: cash flows that come from operations, financing and investing. In essence, the sections on operations and financing display how the company gets its cash while, on the other hand, the investing section shows how the company spends its cash.

43.1 *Cash Flows from Operating Activities*

This section displays how much cash originates from sales of the company's goods and services, less the amount of cash needed to make and sell those goods and services. Undoubtedly, investors have the tendency to prefer companies which generate a net positive cash flow from operating activities. High growth companies, such as technology firms, most of the times tend to show negative cash flow from operations in their formative years. Simultaneously, changes in cash flow that come from operations usually offer a preview of changes in net future income. Actually this is a good sign when it rises. It is also important to watch out for a widening gap between a company's reported earnings and its flow from operating activities. I case net income is pretty higher compared to cash flow, the company might be speeding or slowing its booking of income or costs.

43.2 *Cash Flows from Investing Activities*

This specific section largely depicts the amount of cash the company has spent on capital expenditures, such as new equipment or anything else that is needed to make the business go on. Furthermore, it also contains acquisitions of other business and monetary investments, for example, money market funds.

A company has the potential to re-invest capital in its business at the minimum of the rate of depreciation expenses per year. If it doesn't re-invest, it might show artificially high cash inflows in the present year that may not be sustainable at all.

43.3 *Cash Flow from Financing Activities*

This section portrays the goings-on of cash connected with outside financing activities. Usual sources of cash inflow would be cash raised by selling stock and bonds or by bank borrowings. Similarly, paying back a bank loan would obviously appear as a use of cash flow, as would dividend payments and common stock repurchases.

43.4 *Cash Flow Statement Considerations*

Companies that produce a great deal of free cash flow (**FCF**) attract smart investors. Free cash flow signals a company's ability to pay debt, buy back stock, pay dividends and make easier the development of business. Free cash flow, which is basically the excess cash generated by the company, can be returned to shareholders or invested in new growth chances without hurting the existing operations. Ideally, investors would be interested in seeing that the company can pay for the investing figure out of operations without depending on outside financing to do so. A company's ability to pay for its own operations and growth signals to investors actually indicates that it has got very strong fundamentals. Capital budgeting (or investment appraisal) is the process of defining the viability to long-term investments on purchase or replacement of property plant and equipment, new product line or other projects, as well. Capital budgeting comprises different techniques that are used by managers such as: Payback Period, Discounted Payback Period, Net Present Value, Accounting Rate of Return, Internal Rate of Return and Profitability Index.

As for Capital Budgeting, there are some very significant Decision Tools such as: payback period, net present value (**NVP**) method and the internal rate of return (**IRR**) method. Once projects have been identified, management afterwards starts the financial process of defining whether the project should be pursued or not.

43.5 *Payback Period*

The payback period is the most fundamental and simple decision tool. Via this method it is actually defined how long it will take to pay back the initial investment that is needed to undergo a project. To calculate this, the total cost of the project should be taken and be divided by how much cash inflow it is expected to be received per year. In this way, the total number of years or the payback period will be given exactly.

For instance, if somebody is thinking of buying a gas station which is sold for $100,000 and produces cash flows of $20,000 per year, the payback period is five years. The payback period is possibly best serviced when facing small and simple investment projects. Nevertheless, this simplicity should not be conceived as ineffective. If business is producing healthy levels of cash flow that let a project regain its investment in few years, the payback period can be a highly efficient and effective way to estimate a project. When facing reciprocally exclusive projects, the project with the shorter payback period should be selected.

43.6 *Net Present Value (NPV)*

The net present value decision tool is in fact a very common but efficient process of evaluating a project. To perform a net present value calculation basically needs calculating the difference between the project cost (cash outflows) and cash flows produced by that project (cash flows). As a pretty effective tool, NVP uses discounted cash flow analysis, where future cash flows are reduced at a reduced rate to compensate for the precarious situation that comes from those future cash flows. The term ‘present value’ in NVP concerns about the fact that cash flows earned in the future are not worth as much as cash flows today. As a result, reducing those cash flows back to the present, a comparison is created between the cash flows and the difference is provided with the net present value. Concerning the general rule of the NVP method, independent projects are accepted when NVP is positive and rejected when it is negative. In the case of reciprocally exclusive projects, the project with the highest MVP should be accepted.

43.7 *Internal Rate of Return (IRR)*

The internal rate or return is a discount rate that is typically used to define how much of a return an investor can expect to realize from a specific project. In other words, it is the discount rate that happens when a project is break when or even the NVP equals 0. The decision rule is actually simple: choose the project where the IRR is much higher than the cost of financing. If the cost of capital is 5%, for instance, do not accept projects unless the IRR is greater than 5%. The greater the difference between the financing cost and the IRR, the more attractive the project becomes. The IRR decision rule is unambiguous when referring to independent projects; on the other hand, the IRR rule in mutually-exclusive projects can be really tricky. It is probable two reciprocal exclusive projects to have conflicting IRRs and NVPs, which means that one project has lower IRR but higher NVP than another project. This situation takes place when initial investments between two projects are not equal. In spite of the issues with IRR, it is still a very useful and practical metric that is usually used by businesses.

Businesses have often got the tendency to value percentages more than numbers (i.e. an IRR of 30% versus an NVP of $1,000,000 intuitively sounds much more profound and effective), as percentages have impact on measuring investment success. Capital budgeting decision tools, like any other business formula, are absolutely not perfect barometers but IRR is a highly effective concept that serves its cause in the investment decision making process. An investment appraisal technique similar to net present value method is the adjusted present value. Nevertheless, instead of weighed average cost of capital as the discount rate, to reduce the cash flows from a project ungeared cost of equity is used while an adjustment for the tax shield is provided by related debt capital. Profitability index is an investment appraisal technique which is calculated by dividing the present value of future cash flows of a project by the initial investment that is required for the project.

44. Advantages and Disadvantages of each Method

44.1 *Strengths*

Net present value accounts for time value of money which makes it a stronger approach compared to other investment appraisal techniques, which do not reduce future cash flows, such payback period and accounting rate of return. Net present value is much better than some other discounted cash flows techniques such as IRR. NVP decision should be regarded as preferable in situations where IRR and NVP give conflicting decisions.

44.2 *Weaknesses*

As estimation, NVP is sensitive to changes in estimates for future cash flows, salvage value and the cost of capital, as well. Net present value does not take into consideration the size of project. For instance, say Project A requires initial investment of $4 million to produce NVP of $1 million while a competing Project B needs $2 million investment to produce an NVP of $0.8 million. In case we base our decision on NVP alone, it means we will prefer Project A because it has higher NVP, but Project B has produced more shareholders' wealth per dollar of initial investment ($0.8 million/$2 million versus $1 million/$4 million).

44.3 *Advantages of payback period*

In general, payback period is very simple to calculate as it could be a measure of risk inherent in a project. Since cash flows that occur later in a project's life that are put into consideration are more uncertain, payback period gives an indication of how certain the project cash flows can become. For companies dealing with liquidity problems, it provides a good ranking of projects that would return money early.

44.4 *Disadvantages of payback period*

Payback period does not take into consideration the time value of money that is a serious drawback since it can lead to wrong decisions. Discounted payback period method is a variation of payback method that makes attempts to remove the drawback. It does not take into account any cash flows that occur after the payback period.

45. NVP versus IRR

Net present value is an obvious measure that represents i.e. the dollar amount of value added or lost by taking on a project. IRR is a relative measure as it is the rate of return a project offers over its lifespan. Two of the most widely used investment analysis and capital budgeting decision tools areNVP and IRR. Both of them are discounting models as they take into account the time value of money phenomena. Nevertheless, each method has its strengths and weaknesses and there are situations they do not agree regarding the ranking of acceptability of projects. For instance, there may be a situation in which project A has higher NVP but lower IRR than project B. This NVP and IRR conflict depends on whether the projects are independent or reciprocally exclusive.

In independent projects, the decision concerning acceptance of one project does not affect decision regarding others. Since all independent projects can be all accepted in case they add value, NVP and IRR conflict does not arise, as the company can accept all projects with positive NVP.**Mutually exclusive projects** are those in which acceptance of one project does not include the others from consideration, and the best project is accepted. NVP and IRR conflict is sometimes of crucial importance due to the relative size of the project or the different cash flow distribution of the projects.Since NVP is an absolute measure, it will rank a project adding more dollar value higher without considering the original investment required. IRR is a relative measure and it will rank projects giving best investment return higher in spite of the total value added.

Profitability index is actually a modification of the net present value method which is a complete measure, it gives as the total dollar figure for a project, in comparison with the profitability index which is a relative measure because it gives as the figure as a ration. If the profitability index is greater than 1, a project should be accepted. If the profitability index is 1, stay indifferent. If the profitability index is below 1, the project should not be accepted, too. Profitability index is sometimes called benefit-cost ration and is useful in capital rationing because it helps in ranking projects relied on their per dollar return.

46. Expenses of Installation

The Table below depicts the expenses of the construction and installation of the wind farm. The expenses include the entire equipment cost such as the cost of 50 offshore wind turbines, the jacket foundations. Furthermore, includes the cost of the means to realize the construction, as well as. For instance the table includes analytically the cost of an installation boat for foundations, estimated in real time. The amounts are denoted in millions (M) and in thousands of euro (k).The expenses have been estimated for an average period of 10 months for the construction and installation.

Table 2: The entire cost of Construction & Installation of the Offshore Farm

Cost of Offshore Wind Turbines	600M
Cabling of the Entire Farm	80M
Balance of the Plant	180M
Peflex Protection	700k
Submarine Substation	50M
Jacket Foundations	150M
Installation Cost of the EPC*	320M
Foundation Vessel	13.5M
Modelling and Installing onshore Place(Evoia shore)**	3M
Substation Submarine Vessel	1.89M
Life guarding Vessel, Tugs	500k
Offshore wind turbine Vessel	11.7M
Transportation vessel of Authorized Personnel	1.5M
Power Systems	15M
Personnel Expenses during Construction^	5M
Engineering Team^^	10M
Cost of Advisors, Expenses of EIA,H&S,Licensingetc	10M
TOTAL COST	1.547.790.000

*This cost includes the construction, installation, transportation of equipment **

A place like a stadium size to put together the parts of wind turbines and foundations

***Hotels, feeding, payroll^*

*Supervision, payroll, hotels, transportation, feeding^^*

47. Annual Expenses

The annual expenses of a company are separated in two parts the fix cost and the operating cost. The fix cost is the capitals which are used in order to realize an investment such as the construction of a factory. This cost happens once only. On the other hand, the operational expenses are the expenses which incur normally for a business.

The OPEX, as often abbreviated, includes the payroll, marketing expenses, rents, research & development cost. There is also another expense the CAPEX, Capital Expenses, which include the upgrading or acquiring the capital assets. CAPEX has also estimated for this thesis. The next Table illustrates the expenses of the first year.

Next years are estimated with cash flow analysis including the inflation. This part is depicted in next pages. of the offshore wind farm and these data have been uses for the whole financial analysis. An extended estimation of these expenses is included at the Appendices. The amounts are denoted in millions (M) Euro.

Table 3: Break-down of Annual Expenses

Operational & Maintenance (O&M)	50M
Payroll	3M
Guarding & Security	10M
Unexpected Expenses *	50M
Expenses of Board	10M
Insurance of Investment 1% of profits	4.7M
Rent *	4M
TOTAL EXPENSES	181.7M

O & M→it is standard price for large scale offshore wind farm

Payroll→ includes the salaries for all the personnel from supervisors, senior engineers, workers and supporting personnel. Guarding & Security→ This cost includes the tugs, guarding vessels and the authorized personnel

Annual Income→ Power Yield × Feed-in tariff:

$481{,}627 \times 10^{6} \times 98 \times 10^{-3} = 472.000.000€$ (2)

Insurance→ 0.01× Annual Income:

$472.000.000 \times 0.01 = 4.720.000€$ (3)

Rent→ an amount that is paid to the Authorities for installing and usage of the installation landscape. Unexpected Expenses→ an amount for any unexpected case such as accident, replacement of an element, equipment etc. Expenses of Board→these are the payroll and the facilities such as leasing cars, cell-phone, travel expenses etc.

48. Cash Flows Analysis

The entire analysis is based on the cash flows, which occur from the income of the offshore wind farm, reduced by the annual expenses. The income comes from the total annual power yield "sold" to the National Electricity Company. The amount is really large, because the total annual power yield is large, as well as. The whole analysis realized on Excel solver, in order to gather accurate data. The Expenses include the Investment cost and the annual costs.

The investment cost is spent the first year and over a period of 20 years that is the expected life time of the Investment. The annual expenses include the Operational and Maintenance cost, salaries, security cost, insurance cost and managerial cost.

For more realistic results, the inflation has been embedded on the salaries and managerial expenses. The following figure is a print-screen of first two years of the cash flow analysis. The entire work is at appendices and as an extra file of excel.

Ταμειακές ροές		73,95%	71,63%
		N+0 2017	N+1 2018
Έσοδα από πωλήσεις		**471.994.460**	**471.994.460**
Κόστος O&M		50.000.000	51.000.000
Τέλος ΟΤΑ		14.159.834	14.159.834
Αμοιβές		3.000.000	3.060.000
Εφάπαξ αμοιβή εξωτερικώνσυνεργατών		12.382.320	
Φύλαξη		10.000.000	10.200.000
Έξοδα Διοίκησης		10.000.000	10.200.000
Προβλέψεις		50.000.000	50.000.000
Αδειοδότηση		40.000.000	40.000.000
Ασφάλεια Επένδυσης		4.700.000	4.700.000
Αποσβέσεις		154.779.000	154.779.000
Λειτουργικές δαπάνες		**349.021.154**	**338.098.834**
		-73,95%	*-71,63%*
Καθαρόλειτουργικόκέρδος		**122.973.306**	**133.895.626**
		26,05%	*28,37%*
Οικονομικά αποτελέσματα		**-63.192.303**	**-58.180.468**
Δαπάνες		*-13,39%*	*-12,33%*
Κόστοςεξυπηρέτησης δανείου (τόκοι)		-63.192.303	-58.180.468
Έσοδα			
Μικτόκέρδος		**59.781.003**	**75.715.158**
		12,67%	*16,04%*
Φόροι		17.336.491	21.957.396
Λειτουργικές ταμειακές ροές		201.923.512	213.236.762
	-1.547.790.000	201.923.512	213.236.762
Καθαρόκέρδος		**42.444.512**	**53.757.762**
		8,99%	*11,39%*
Ετήσιες ταμειακές ροές		**201.923.512**	**213.236.762**
		42,78%	*45,18%*
Χρεολύσια		81.674.471	86.686.307
Ετήσιεςδιαθέσιμες ταμειακές ροές		**120.249.041**	**126.550.456**
Συνολικέςδιαθέσιμες ταμειακές ροές		**120.249.041**	**246.799.497**
-464.337.000		**120.249.041**	**126.550.456**
Debt Service Coverage Ratio (DSCR)		1,95	2,03

Figure 17: Print –Screen of Part of Cash Flows

The budgeting has a 30-70% configuration and the rate of lending is 6%. According to the Excel, the IRR of the Investment is 13%, really high compared to similar investments, which shows an IRR of 7 to 9%. The payback period is the same with break- even point, where expenses are equal to income, and occurs at approximately 4 years. The IRR of Equity is also really high, as it is 27%. At this point, it is important to highlight the difference of Project IRR and IRR on Equity, because it is really tricky and sometimes confuse the investors. The project IRR takes the total amount of inflows for the investment, while the IRR on Equity takes into account only the private capitals. As for the IRR on Equity there is the assumption that there is a dept. In other words, for the IRR on Equity, the inflows are the cash flows reduced by the dept. Another indicator is the CAPEX, the Capital Expenditure. The capital expenditure depicts the funds which are used to increase physical assets such as new equipment, property, industrial buildings etc. This indicator is necessary to undertake new projects or investments by the firm. Furthermore, it illustrates the new scopes of their operation, such as installing or extending the investment etc. The debt service coverage ratio, denoted as DSCR, refers to the total cash flows which are necessary to serve the annual payments and debts. This is used for bank loans to check the ability to serve the depts. This indicator is a ratio of the net present income to total debt service. The investment DSCR is 1.98, which can be characterized really decent to serve the debts and payments. The entire cash flow analysis is included in the Appendices part.

CAPEX is approximately 4.000.000 million per MW.

CAPEX €/MW	**3.869.475**
CAPEX / μέσο EBITDA (στα 20 έτη)	**5,56**
Μέσος κύκλος εργασιών στα 20 έτη	**3.928.812.209**
Ποσοστόιδίωνκεφαλαίων	**30,00%**
IRR on equity (στα 20 έτη)	**0,27**
IRR on project (στα 20 έτη)	**0,13**
Μέσο DSCR	**1,98**
Ελάχιστο DSCR	**1,94**
Νεκρόσημείο (Break-even point)	**3,77 έτη**

Figure 18: The IRR Data, Break Even point, DSCR AND CAPEX

49. Sensitivity Analysis

Sensitivity analysis is a method that helps the analyst to predict how the changes in one variable can influence the entire outcome. This technique shows how different values of an independent variable cause changes in the dependent variable, under specific circumstances and assumptions. The sensitivity analysis is also well known as what-if analysis or simulation analysis, giving the proper decision by a specific range of variables. For instance, sensitivity analysis can examine how the changes on interest rates will influence a bond price. This financial tool is really useful in "Black Box Process", where the outcome is an opaque function of multiple variables. This process can be practiced in every sector from medicine to economics and engineering, for instance. This tool will examine how different changes on independent variable on the offshore wind farm will cause changes in the dependent. The independent variables will be the price/tariff of kWh, the OTA tax and will examine how this certain range will cause changes in the dependent variable, the IRR. The sensitivity analysis has been realized on Excel. Practically, the assumptions will be connected with the cash flows on Excel.

Φόροι και τέλη		
Τέλος ΟΤΑ - Έτη 1-20	0,03	κύκλουεργασιών
Περίοδος αποσβέσεων	10	έτη
Φορολογικόςσυντελεστής επιχείρησης	29%	
Εφάπαξ αμοιβές εξωτερικώνσυνεργατών	0%	του CAPEX
Αμοιβές	2%	κύκλουεργασιών

Figure 19: Depiction of OTA TAX and the 29% taxation of the Investment

The first sensitivity analysis refers to the changes of the tariff of kWh, taking a range from 5 cents to 12 cents, including the 9.8 cents real tariff. The second attempt is a sensitivity analysis of OTA tax with range from 0.01 to 0.05, including 0.03. The combination of the larger value of OTA tax and the smaller of kWh price gives a negative value of IRR, -0.05. The following figure depicts the whole sensitivity analysis and how the change of tax and tariff impact on the IRR. The market tariff gives high values of IRR. Keeping this price and changing the OTA tax infinitesimal changes occur on IRR. Also, as the market price increase, IRR grows, as well as. On the other hand, as the OTA tax increases, the outcome decreases. The best combination is high market tariff and low OTA tax. For instance, the best option is the lowest examined OTA tax, and the highest market price, respectively. The exact impacts on IRR are depicted on the following table of the sensitivity analysis, as extracted from Excel.

Table 4: The outcomes of Sensitivity Analysis

0,13	0,01	0,02	0,03	0,04	0,05	
5	-0,049185807	-0,053217662	-0,057403472	-0,061760334	-0,066308418	
6	0,010419375	0,008104431	0,005789631	0,002780883	-0,00048748	
7	0,047305079	0,044804777	0,042293727	0,039761297	0,037207053	
8	0,080697177	0,078209285	0,075662708	0,073062428	0,070401313	
9,8	0,130446625	0,127871709	0,125282468	0,12267833	0,120058693	
12	0,184880352	0,181988498	0,179086805	0,176174868	0,17325226	

50. Conclusions

The offshore wind farm is located at the North Aegean Sea, 12km away from Evoia Island. The distance of the entire park from the land is 12km. This particular allocation drastically minimizes the cost of submarine cables and the installation expenses. This wind farm will produce electricity, which can serve more than 150.000households annually. The installation is interconnected with the 400kV high voltage transmission lines of Evoia’s mainland.

The construction, installation and the entire equipment meet the global trends, requirements and IEC protocols, as well. An extremely deep investigation in the European market has taken place in order to follow the typical process of a feasibility report as for an offshore wind farm installation. As it was pretty hard to find any valuable data in Greek market, European directives, legislation and protocols have been used. Moreover, both the layout of the infrastructure has been based on the EIA and all the environmental impacts have been mitigated in order to avoid irreparable impacts at the flora and fauna of the North Aegean Sea. Apart from that, a completed risk assessment has also taken place. Following the designated areas from the WWF's map for feasible offshore wind farm, the place of installation can be characterized as the most appropriate one. The wind rose diagram proves that the best wind speed, compared to the other designated areas, is at this region. The infrastructure is stable and founded on jacket foundations, which are preferable by the bathometry and morphology of the area. Protection schemes for the whole installation have been installed, in order to prevent collapses and hazards.

As far as the financial analysis, the indicators have been examined are the IRR, depreciation CAPEX, IRR of Equity, Cash Flows and Breakeven Point. The IRR of the wind farm can be characterized really high, approximately 13%, while other renewable projects such as onshore wind farms and large scale PV projects show 8-9% and 7-8% IRR, respectively. The depreciation is same and it receives the return of capital in 10 years' time.The examination of NPV was hard due to the mismatching and lack of market data, such as the growth. For more realistic results, the European inflation has been included in the calculations. This investment is feasible and sustainable with payback period approximately at 4 years and really high Project IRR of 13%. So the investors can undertake the decision to invest on this project, due to the fact that it shows an IRR of Equity of 27% and DCSR of 1.98.Finally, the Break-even is approximately at 4 years, while the whole lifetime is 20 years.

51. Discussion

The main objective of this dissertation is the examination of the feasibility of an offshore wind farm in Greece. Following the steps of a typical feasibility report the outcomes are really positive. An extended research on wind technology, literature review and market the thesis includes updated data, which can be used in real life. Apart from the research part and engineering perspective, the thesis is concluded with a financial analysis, which conducted for this scope; to support or not the investment in Greece. The outcomes are really beneficial and the whole investment can be characterized as profitable, according to financial indicators, which have been used and explained on the previous part. The investment is attractive with payback period on 4 years and IRR larger than other investments such as Photovoltaic plants, onshore wind plants etc.

52. Recommendations and further work

This section will illustrate recommendations for further work on this feasibility report, taking into account the equipment, the financial data and the analytical approaches. The scope of this project follows typical paths of a feasibility report, so new approaches are suggested. In order to commit an entire analysis if an offshore wind farm is really profitable, other parameters apart from the IRR should be investigated. The Net Present Value is preferable in case of accepting or leaving this investment. To examine NPV market, specific data is also necessary, such as the growth of market, which is extremely difficult to calculate.

The realization of the same project in different designated areas in Greece can change the power yield and the entire cost in general, as well. On the other hand, the installation of the same project with the same nominal power but using different equipment is also taken into consideration in order to have a general view of prices around the world and how this can influence the entire cost, the payback period, the cash flows and the depreciation. Another recommendation is the compare and contrast of projects that meet similar characteristics such as power yield, construction cost, wind speed etc. In this case, only projects that are located around Europe can be examined, because the sector of offshore wind farms in Greece shows a dead end. Leaving the monopsony of Public Electric Authority in Greece, we can examine the case of different Grid clients, which are interested in buying the produced power from the offshore wind farm. This will be helpful to examine how the tariff of the kWh can be configured and also examine the trends and the demand in the private sector of Electricity in Greece, eliminating the monopsony of Public Authority in Greece. A regression model will be useful to find similarities referring to a large amount of data in order to compare and contrast the trend of the sector in Greece with offshore wind farm sector in other European countries, such as Denmark, UK etc. Furthermore, another type of budgeting can be examined, such as the use of hedge funds, and also investigate the leverage degree. Last but not least, Economic Added Value (EVA) can consider critically the cost of private capitals as an opportunity cost and then calculate the real annual increase of the shares without capital costs. Another Recommendation is the extended use of offshore wind farms, due to the fact that they are suitable to empower a large number of households and can eliminate the energy poverty phenomenon. People under the bottom line of poverty can afford the cost of energy and this phenomenon has launched in Greece during the last eight years. With the extended installation of infrastructures with large power yield, these households can be supported. Last but not least, another proposal is the investigation of Economies of Scales in the offshore wind industry. This can enlighten us by compare and contrast large offshore wind farms across Europe and how the pressures of prices can result in the extended installation of them and the annual profit.

53. APPENDICES

Gantt Chart

Process	1st Semester	2nd Semester
Research	x	
Technology Review	x	
Market Analysis		x
Contact with Market Players		x
Layout of Wind Farm		x
Define Expenses & Profits		x
Wind Turbine Comparison		x
EIA/H&S	X	
Thesis write-up		X

The Gantt chart depicts how the time splits in order to realize this thesis.

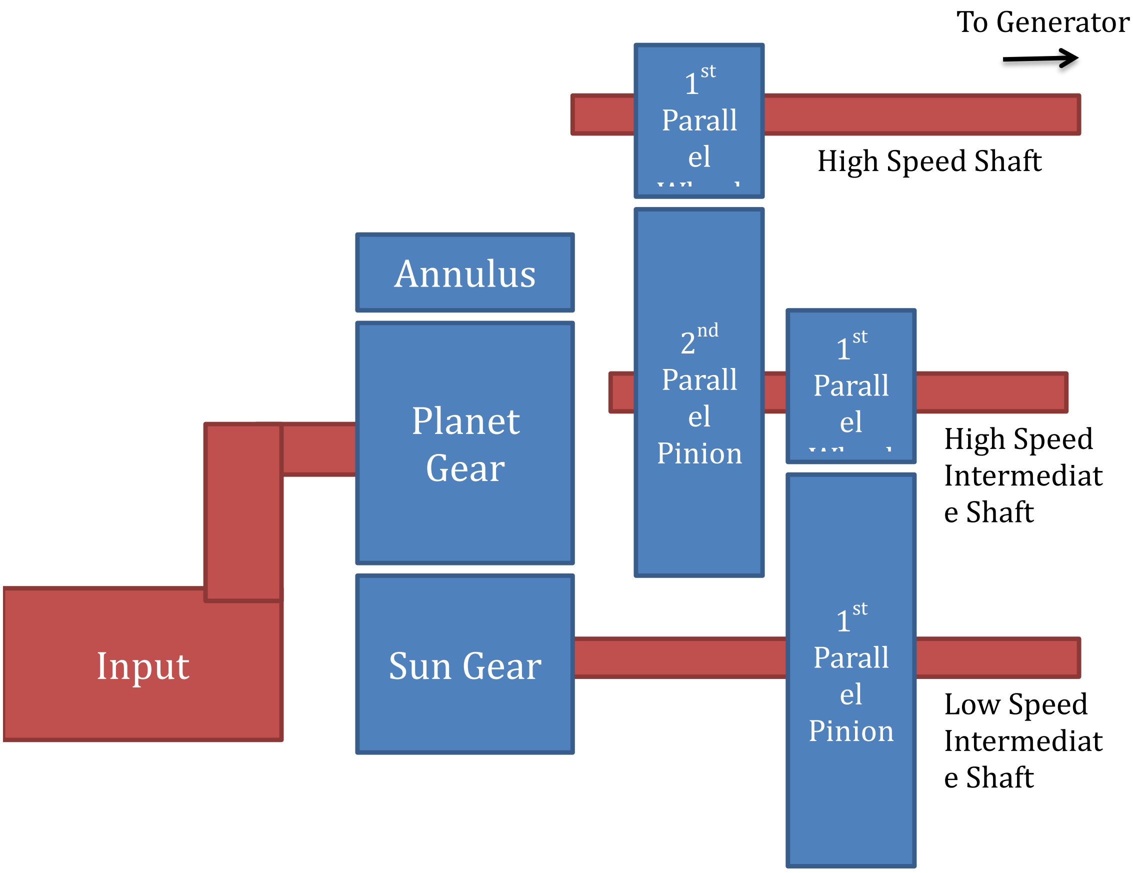


Figure 1: Schematic of Gearbox

Table 1: Gearbox Sizes

Gear	Sun	Planet	Annulus	1^{st} Pinion	1^{st} Wheel	2^{nd} Pinion	2^{nd} Wheel
Teeth	18	27	72	84	18	81	18
Dp /mm	360	540	1440	1344	288	1296	288
Width /mm	220	220	220	192	192	50	50

54. Risk Assessment (A)

For the development of the Construction HSE Plan the following sources were used:

- UK & European legislation for safety at construction sites (indicative CDM 2007, P.I. 172/2002 and 92/57/EEC).
- The requirements of the project thesis.
- The requirements of equipment which will be used in the work.
- The Health and Safety Executive (HSE) website.
- Good safety practices, according to the rules of science and IEEE.
- The International Health and Safety at Work Revision Guide: For the NEBOSH International General Certificate.
- International Health and Safety at Work Revision Guide: For the NEBOSH International General Certificate.
- Health and Safety Presentation, by Atkins.
- Engineering Studies of M.Eng. Cardiff University.

Analytically, H & S procedures are documents with live update during the undertaking and construction of the project. A checklist of HS should include the fundamental requirements to prevent hazards and this should be updated at every stage of the construction. The principal points are:

- Hazards identification for risk prevention
- Hazards elimination
- Facing of hazards ab ovo
- Preventive remedies and risk assessment
- Replacing of hazardous/dangerous materials, tools and equipment
- Methods, processes and extensive descriptions of the equipment to prevent any trauma or danger from the personnel.

Risk Assessment (B)

For health and safety reasons, it is important to follow a systematic process for potential hazards and risks, in order to protect authorized or unauthorized personnel, which has been involved in a project installation. The Risk assessment includes the following crucial steps:

- Identification of potential hazards-dangers.
- Evaluation and analysis of the hazards.
- Determine the ways and remedies to protect from the hazard.
- Actions implementing risk control, known as **risk control**.

The implementation of a risk assessment is really of critical importance, mainly in large scale and long term projects, such as the installation of the offshore wind farm. This process clarifies the potential hazards and the persons who can get involved in hazards. Furthermore, this method determines whether a control program is appropriate for a particular danger by evaluating and prioritizing the hazards and risks, implementing control methods and preventing injuries and illnesses that can be caused during the design or planning stage of the investment.

The main goal of a risk assessment is to answer four crucial questions:

- What can be wrong and under what circumstances and what are the possible consequences?
- Who is under the hazard?
- What is the likelihood to occur this hazard?
- Is the hazard easily controlled or further remedies are appropriate?

A risk assessment should be completed, before new activities or stages are introduced and of course when a hazard has been identified. An entire Risk Assessment is illustrated at Appendices section for an installation of an offshore wind farm.

55. General Health and Safety Rules and Checklist

The following principal Health and Safety measures should be followed on site of construction. The square denotes that this should be checked before the beginning of any procedure.

- ☐ Workers do not start any work without taking the induction safety training from the safety supervisor.
- ☐ Workers are following the instructions that are provided from their supervisor.
- ☐ On site, everybody should follow Health and Safety site rules and good practices.
- ☐ All works carried out in confined spaces will be managed and controlled by an employee who is trained and competent on a safe system of work procedure.

- Work will not be assigned to any individual if he/she is not bodily and mentally suitable for it.
- Everybody selects and applies safe working methods, taking the proper precautions for him/her self and others.
- Suitable tools are selected for each work.
- Equipment is maintained regularly, according to manufacturer's manual/ instructions, and is CE (Certified Equipment) marked.
- Electrical works are executed by trained and licensed electricians.
- Everybody on site should **use, as a minimum, safety helmet, shoes, and reflective vest**. Administration facilities are excluded.
- Minimum requirement for safety shoes is to have protective shielding for the toes and the sole (EN 345 S3 Requirement)
- Safe access/ egress should exist for every working position and area.
- Everybody should comply with site safety signs.
- Fire is prohibited on site.
- Nobody is allowed to work under the influence of drugs and alcohol.
- Nobody is allowed to move, remove, relocate or modify existing safety measures.
- Workers are obligated to report any unsafe working condition and to stop working until they get the proper assistance.
- Scaffolding will be erected according to legislation (P.I. 497/2004).
- Proper full body safety harness will be utilized by employees working at height, unless there is sufficient protection by means of side protection and working floor.
- Site should be clean and tidy. Litter should be placed in the provided bins.
- Authorized and trained personnel are handling the equipment on site.
- All cranes should be certified and operators should have experience and valid licenses.
- Speed limit at the site is 12 mph.
- Visitors should be inducted for safety and be escorted by authorized personnel.
- Smoking is allowed only at designated areas.
- A three strike rule will be applied on site.
- All incidents should be reported to the safety coordinator.

Note: In case of conflict of the above general safety measures with specific measures then the specific will apply. Further investigation should be held where is needed.

The contractor has to be informed in advanced if any **visitor** is to arrive on-site. Every visitor will be given a visitor access pass, which has to be visible at all times and has to be returned on leaving the site. Each visitor: a) will be escorted from the Renewable Energy Park main gate to the administration offices. b) In case that he/she has to visit the working area, he/she has to be inducted in safety by the H&S coordinator. c) The PPE has to be utilized when he/she is not in administration offices. d)He/she has to be accompanied all the time during his/her visit in the working area.

55.1 *Welfare Facilities*

The hygiene is essential. The contractor will ensure that appropriate washing and toilet facilities and drinking water will be available for all personnel on site. Site manager/supervisor and safety coordinator will recommend the location of these facilities.
Also, protected and shaded rest area/canteen will be provided for the personnel on site, by the main contractor. Shaded, secure areas shall be created in the work site close to the working areas for personnel to take short breaks.

The number of toilets that will be installed on site, according to legislation (CDM 2007, No.320), depend on the number of personnel on site.

Table 2: The number of facilities according to workers

Number of Personnel (male)	Minimum number of facilities	
	Toilets	Urinals
Up to 15	1	1
Up to 25	1	2
Up to 50	2	3
Up to 75	3	4
For every 35 persons additional	1	1

Number of Personnel (female)	Minimum number of facilities
	Toilets
Up to 15	1
Up to 30	2
Up to 50	3
Up to 70	4
For every 30 persons additional	1

55.2 *Hazards and Preventive Remedies /Measures for every stage of the Project*

In this part of HSE Plan the hazards and the required preventive measures will be described for every phase of the project. Health and Safety supervisor of the company that will be assigned with a particular work, with the assistance of safety coordinator during the construction phase, has to confirm the fulfillment and the validity of the data, taking into consideration the data that will result from the methodology, the materials and the way of construction.

The content of the following instructions is going to be supplemented/revised by the Health and Safety supervisor of the company that will be assigned with the particular work and he/she will be assisted by the safety coordinator during the construction phase. Then the instructions will be distributed from the Safety Coordinator to engineers, foremen and sub-contractors.

The sub-contractors have to inform their personnel about these instructions, with the involvement of the Safety Coordinator.
The content of instructions should be considered during the planning of the works and should be followed during the implementation of the work. The following table illustrates the hazards that should be phased and the protective means (Appendix H S. Kommodromos).

Table 3: Hazards that should be tackled and protective measures (Appendix H. S.Kommodromos)

A/A	TASKS	HAZARDS	PRESERVATIVE SAFETY MEASURES
	Excavations and backlifting	Hit by the equipment/ machine	Licensed operator.
			Continuous supervision of the excavating activities.
			Reverse alarm in operation.
			Use of high visibility vest.
			Speed limit applied 12 mph.
			Manufacturer Safety load limits are not exceeded.
			Vehicle movement on site is coordinated.
		Noise	Equipment with silencers.
			Use of earplugs.
			Maintenance of machinery and trucks.
			Safety signs
		Dust, debris	Equipment with silencers.
			Use of earplugs.
			Maintenance of machinery and trucks.
			Safety sign.
			Equipment with silencers.
		Falls	Soil examination.
			Checks/inspections of equipment.
			During works no one approaches machinery, especially in position that operators' visibility is low (ex. behind machinery).
			Fences placed in the perimeter of construction site and the excavations, at least 200cm height.
			Excavations walls support - reinforcement to prevent collapsing, if necessary.
			Safe walkways over trenches and pits.
			Continuous utilization of Personal Protective Equipment (P.P.E).
			Other workers should not be near while there is an excavation process.
			Work supervision.
			Inspection of excavation after heavy rain and other emergency situations.
			Signs to indicate the hazard of falls in excavations.
			Deposition of materials and objects is avoided near the excavation edges. Safety distance at least 1m.
			Proper accesses placed in excavation. At least 2 points of access/egress in each excavation.
		Electrocution (Utility Lines – electricity, water,	Check existing plans for utility lines. Safe condition of underground utility lines is ensured

		fire extinguish system)	Work permit.
			Immediate stoppage of works if utility lines are found and inform site engineer and EAC.
			Use of P.P.E
			Trained and experienced personnel.
			Work supervision.
	Concrete works	Hit by the pump	Pump in good condition.
			Pump instalment in solid ground and usage of 50X50cm kevels (depends on weather conditions and from the soil).
			Check pump before first use of day/shift.
		Cement in the eyes	Use of glasses EN 166.
			Immediate wash.
		Cement in the body	Use of safety gloves.
			Use of safety boots.
			Use of coveralls.
		Vibrations from equipment (white finger syndrome)	Use of anti-vibration gloves.
			Use of Certified Equipment (CE).
			Equipment is maintained regularly, according to manufacturer guidelines.
		Falls into excavation	Safe installation of pump – minimum 60cm from excavation edges.
			Proper fencing
	Working at height	Falling objects	Use of safety helmets.
			Safety signs.
			Sufficient lighting.
			Experienced personnel.
			Work supervision.
			Restriction of working area.
			Use of tool belt.
			Securing materials, equipment, tools etc.
		Fall from height	Use of safe access/egress.
			Safe working floor.
			Use of safety harnesses, where needed.
			Handrails.
			Safety “life line” , where required.
			Emergency plan for retrieval of suspended personnel working at height.
			Experienced and trained personnel.
			Safety Signs.
	Ladders	Fall from heights	Use of handmade wooden ladders and of damaged ladders is prohibited.
			Only one person at a time should stand on portable ladders.
			While ascending or descending a ladder, personnel are facing the ladder and they are using both hands to grip the side rails.

			Ladder extends at least 1m from the working area.
			Place the ladder angle so that the base is at least 1m out for each 4m (slope 4 to 1) of ladder working length (support point to the base).
			Ladders should be tied and secured.
			Personnel should utilize tool belts when climbing a ladder with tools or equipment.
			Use of P.P.E – Above 2m, safety harness is required.
			Work supervision.
			Experienced and trained personnel.
		Falling objects	Personnel should not pass under ladders.
			Personnel should utilize tool belts when ascending or descending a ladder with tools or equipment.
			Use of P.P.E.
			Safety signs.
	Use of lifting equipment	Lifting equipment overturns	Installation study.
			Licensed operator.
			Visual contact with object (trained rigger in case that there is no visual contact between operator and object).
			Proper installation on solid ground.
			Use of outriggers.
			Use of counterweight.
			Study the weight and lifting route.
			Restriction of lifting operations when there are bad weather conditions (wind above 10m/s) and/or large load surface.
		Lifting equipment collapses	Certified lifting equipment.
			Lifting capability diagram.
			Study the weight and lifting route in relation to the lifting capability of equipment.
			Regular maintenance of lifting equipment and repair in case of failure by experienced personnel, according to constructor's manual.
		Falling load	Certified lifting accessories – equipment (CE marked).
			Load is tied by an experienced rigger.
			Area under load restricted.
			Workers and others are not UNDER LOAD route.
			Use of safety helmets and reflective vests by the workers in the area.
			Check for compatibility of lifting equipment and accessories.

			Regular maintenance of lifting equipment according to maintenance plan of crane
			Placement of lifting diagram in visible position.
			Restriction of lifting operations when there are bad weather conditions (wind above 10m/s) and/or large load surface.
			Wind indicator (meter) is installed on crane.
			Sufficient lighting.
			Breaking systems.
			Restriction of free load swing.
		Falling from height because of hit from hook etc	Experienced and trained personnel.
			Visual contact of the load by operator.
			Communication between rigger and operator.
			Use of handrails.
			Use of safety harnesses.
		Load hit	Visual contact between operator and load.
			Work interruption.
			Restriction of lifting operations when there are bad weather conditions (wind above 10m/s) and/or large load surface.
			Experienced rigger in communication with operator.
			Vertical lifting of load.
			Licensed operator
		Electrocution	Electrical panel protection from weather conditions, equipment, third parties access etc
			Use of RCDs.
			Regular inspection of cables.
			Restrict lifting near live overhead cables.
		Thunder strike	Equipment and/or working area protected from thunder.
		Assembly/ Modification/ Disassembly of lifting equipment	Assembly/Modification/ Disassembly of lifting equipment from trained and experienced personel
			Working according to manufacturer's instructions/ guidelines.
			Working area restricted.
			Safety signs in place.
			Work supervision.
	Vehicles/ Machinery	Accidents	Signs.
			Traffic control.
			Vehicles/ machinery in good condition (breaking systems, mirrors, tyres, lights etc)
			Use of signalmen.

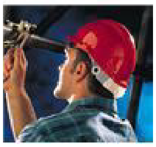
			Proper selection of tools – use the correct tool for each work.
			Maintenance of equipment.
			Immediate repair of failure by trained personnel.
			Dry working floor.
		Flying particles/ Noise	Use of the P.P.E – safety glasses, earplugs, gloves etc
			When using a grinder, a visor can be used in addition.
			Tools with proper guards.
			Equipment CE marked.
	Electrical installations/ works	Electrocution	No contact with electrical conductors.
			Minimize the cables on the ground (cables are recommended to be underground or overhead).
			Minimize unprotected cables on the ground (cables in proper tubes)
			Regular inspection of equipment.
			Double insulation Hand Tools/ Power Tools.
			Use of short length cable extension.
			Electrical panel protected - locked.
			Safety Signs in place.
			Installation of RCD 30mA.
			Experienced personnel – Licensed electricians.
			Lock out/Tag out procedure.
			Use of proper safety shoes.
	Wind Turbine Tower Erection	Fall from height	Experienced and trained personnel.
			Use of protective net, if required.
			Use of safety harnesses.
			Use of lifting equipment.
			Lifting equipment is properly maintained according to manufacturer's manual.
			Use of "life lines"
			Health check.
			Emergency procedures.
			Work supervision.
		Falling objects	Use of safety helmets.
			Restrict approach under working area.
			Use of tool belt.
			Materials etc are properly secured and tied.
			Lifting materials by using proper lifting equipment.
		Use of grinder (cuts, electrocution, particles)	Tools with proper guards.
			Regular maintenance of equipment.
			Cable inspection.
			Protection in case that guard falls from height.

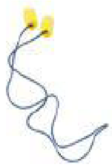
	Works in all phases	Different work teams in same working area	Coordination of works.
		New or unskilled personnel	Training of personnel.
			P.P.E distribution.
		Hygiene	Adequate welfare facilities.
			Bins are placed.
			Regular cleaning.
	Road works	Road traffic accident	Licensed drivers/operators
			Abide by the traffic regulations
			Vehicles/machinery in good condition (lights, tyres, reverse alarms, brakes, etc).
			Strict traffic rules on site.
			Plan for access route for heavy vehicles.
			Segregate traffic from people movement.
			Check for height restrictions (underpasses, site structures).
		Collisions of vehicles/ machinery with personnel - third party vehicles	Concrete blocks, signs, reflective cones and safety (flashing) lights have been placed.
			Workers utilize P.P.E including HV (High Visibility) - reflective vest.
			Worker responsible for traffic control.
			Machinery/ vehicle movement is coordinated.
			Safe accesses and exit routes to-from working areas.
			Road is cleaned from materials and tools.
			Workers are trained and experienced.
			Segregate traffic from people movement.

All personnel have the following obligations:

- To follow health and safety rules. To take care of themselves and others that are affected by their acts or omissions.
- For the accomplishment of the set targets, according to their training and supervisors'/foremen' instructions, they must:
  - Use properly machines, tools, hazardous substances, vehicles etc.
  - Use P.P.E as required and maintain them in good condition.
  - Not to tamper with, by-pass, alter or remove any safety devices.
  - To report immediately to their supervisor (or to the Health & Safety Officer), any situation that could cause risk to Health & Safety and also every deficiency that is observed in the safety systems.
- To attend seminars or educational programs for health and safety issues.

<table>
<tr><td colspan="2">WORK POSITION: Personnel working at height.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORK PLACE</td></tr>
<tr><td>- Falling from height</td><td>- Falling from height</td></tr>
<tr><td colspan="2">TIME OF USE: During work at height above 2m without safety protection i.e no handrails.</td></tr>
<tr><td colspan="2">ERGONOMIC REQUIREMENTS:</td></tr>
<tr><td colspan="2">CHARACTERISTICS OF PERSONNEL: -</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Safety harness can be used with other P.P.E at the same time such as safety helmet, safety boots, safety glasses, gloves, earplugs etc</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• 5 point Safety harnesses.
• Easy, fast, comfortable and good fit.
• Lanyards with ‘shock absorber’ for the protection of the back and spine from injury that can occur from a fall.
• The final length of lanyard should be smaller than the lower level for the avoidance of impact in case of a fall.
 1  2  3  4 5
1 Safety Harness
2 Lanyard with Karabiner
3 Safety Harness
4 Webbings Lanyard
5 Adjustable Shock Absorbing Lanyard with Scaffold Lock</td></tr>
<tr><td colspan="2">WORK POSITION: Personnel working on site.</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Safety glasses</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>- Flying particles
- Fuel and chemicals</td><td>- Solar radiation
- Dust</td></tr>
<tr><td colspan="2">TIME OF USE: Continuous.</td></tr>
<tr><td colspan="2">ERGONOMIC REQUIREMENTS: -</td></tr>
<tr><td colspan="2">CHARACTERISTICS OF PERSONNEL: -</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Safety glasses can be used with other P.P.E at the same time such as safety helmet, safety boots, safety glasses, gloves, earplugs etc</td></tr>
<tr><td colspan="2">SPECIFICATIONS THAT SHOULD BE FULFILLED:
 1  2  3
1 Keep safe Chemical/Dust Anti-mist Safety Googles
2 Safety Googles
3 Safety Anti-mist Googles</td></tr>
</table>

<table>
<tr><td colspan="2">WORK POSITION: Personnel on site</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Safety helmet</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>- Fall</td><td>- Falling objects
- Hit by or to equipment
- Electricity</td></tr>
<tr><td colspan="2">TIME OF USE: Continuous</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Helmet can be used with other P.P.E at the same time such as safety boots, safety glasses, gloves, earplugs etc.</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• Size adjustment
• Insulated for electrocution avoidance
• Internal vibration absorber system
• Changes falling objects direction without retain them.
• High resistance from falls of heights.
• High resistance in pressure.
• Ventilation of the head and preventing it of heating.
• Light
 1  2
1 Reduced Peek Roofer Helmet
2 Reduced Peak Safety Helmet</td></tr>
<tr><td colspan="2">WORK POSITION: Personnel on site</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Safety boots</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>- Falling objects
- Manual handling of loads
- Fuel, lubricants, cement
- Hot materials</td><td>- Slippery working floor
- Static electricity
- Rain</td></tr>
<tr><td colspan="2">TIME OF USE: Continuous</td></tr>
<tr><td colspan="2">ERGONOMIC REQUIREMENTS: Light, available in all sizes, good feet “breath”</td></tr>
<tr><td colspan="2">CHARACTERISTICS OF PERSONNEL: -</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Safety boots can be used with other P.P.E at the same time such as safety helmet, safety glasses, gloves, earplugs etc.</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• Finger protection from impact
• Waterproof
• Antistatic soles and high resistance to chemicals, fuels etc
• Absorbing vibrations
 1  2
1 Full Safety Boot with midsole
2 Safety Boot with midsole</td></tr>
</table>

<table>
<tr><td colspan="2">WORK POSITION: Technicians, machinery operators.</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Safety gloves for mechanical hazards.</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>• Hits
• Cuts</td><td></td></tr>
<tr><td colspan="2">TIME OF USE: As long as it is required.</td></tr>
<tr><td colspan="2">ERGONOMIC REQUIREMENTS: Available in different sizes.</td></tr>
<tr><td colspan="2">CHARACTERISTICS OF PERSONNEL: -</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Safety gloves can be used with other P.P.E at the same time such as safety helmet, safety glasses, earplugs etc.</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• Good hand application.
• To be accompanied from instructions of use and maintenance.
• To be available in different sizes.
• To have good capability of holding materials.
 1  2  3</td></tr>
<tr><td colspan="2">WORK POSITION: Operators, technicians & supervisors.</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Earplugs</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>• Power tools such as vibrators, abrasive wheels etc</td><td>• Pumps motors
• Vehicles and machinery engines
• Generator
• Equipment</td></tr>
<tr><td colspan="2">TIME OF USE: When power tools are used, noisy equipment and where there is a safety sign for noise (i.e because of generator).</td></tr>
<tr><td colspan="2">ERGONOMIC REQUIREMENTS: Available in different sizes.</td></tr>
<tr><td colspan="2">CHARACTERISTICS OF PERSONNEL: -</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Earplugs can be used with other P.P.E at the same time such as safety helmet, safety glasses, earplugs etc.</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• To be accompanied from instructions of use and maintenance in English language.
• To be available the equipment for maintenance.
 1  2  3 </td></tr>
</table>

<table>
<tr><td colspan="2">WORK POSITION: Personnel on site.</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Reflective vest</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>• Falling objects
• Machinery/ vehicles</td><td>• High visibility demands</td></tr>
<tr><td colspan="2">TIME OF USE: Continuous.</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Reflective vest can be used with other P.P.E at the same time such as safety helmet, safety glasses, earplugs, overalls etc.</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• To be available in different sizes.
 1  2</td></tr>
<tr><td colspan="2">WORK POSITION: Personnel on site.</td></tr>
<tr><td colspan="2">TYPE OF P.P.E: Safety shoes</td></tr>
<tr><td colspan="2">HAZARDS</td></tr>
<tr><td>FROM WORK</td><td>FROM WORKPLACE</td></tr>
<tr><td>• Power tools such as vibrators, abrasive wheels etc
• Falling objects
• Manual handling
• Fuel, lubricants
• Hot materials
• Step on sharp edges or dangerous surfaces.</td><td>Slippery working floor
Static electricity
Rain</td></tr>
<tr><td colspan="2">TIME OF USE: Continuous</td></tr>
<tr><td colspan="2">ERGONOMIC REQUIREMENTS: Light, available in different sizes, good foot “breath”.</td></tr>
<tr><td colspan="2">CHARACTERISTICS OF PERSONNEL: -</td></tr>
<tr><td colspan="2">OTHER P.P.E THAT ARE USED AT THE SAME TIME: - Safety shoes can be used with other P.P.E at the same time such as safety helmet, safety glasses, earplugs etc.</td></tr>
<tr><td colspan="2">P.P.E SPECS:
• Good foot “breath”
• Light
• Waterproof
• Antistatic soles and high resistance to chemicals, fuels etc
• Absorbing vibrations
 1  2</td></tr>
</table>

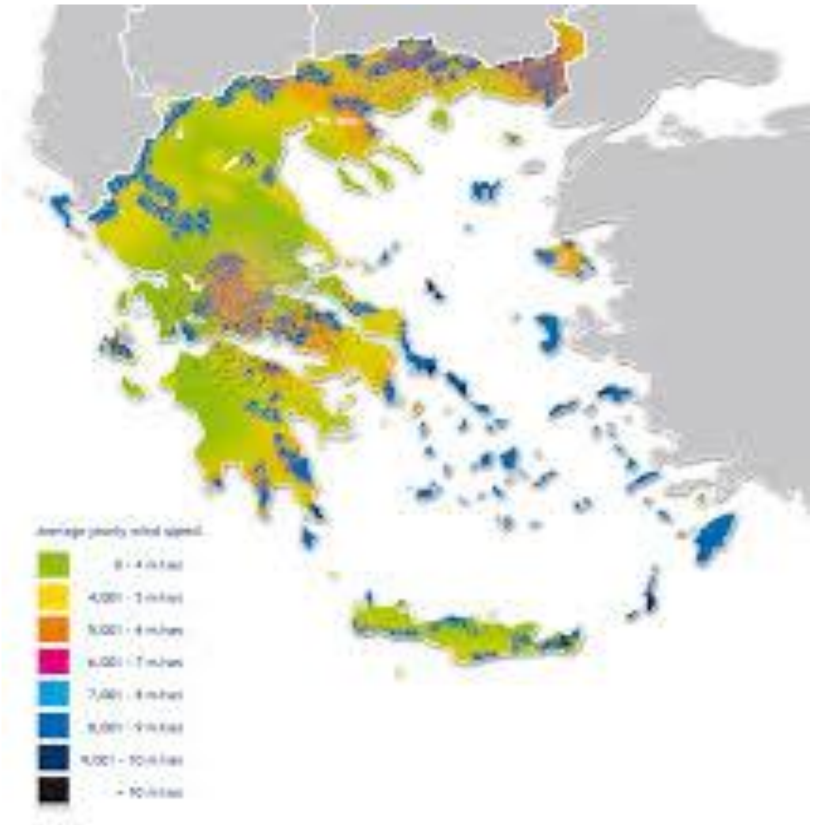


Figure 2: WWF's map denotes the suitable location on North Aegean.

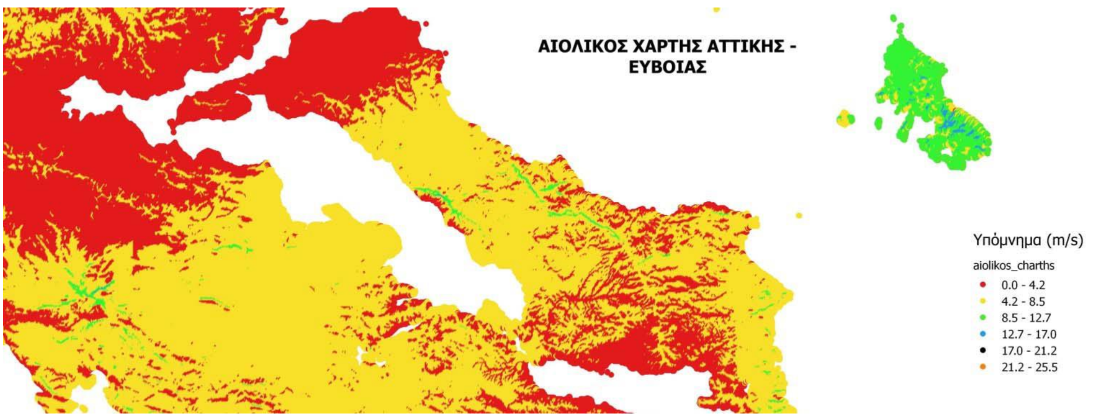


Figure 3: Wind Speed Map of North Aegean close to Evoia

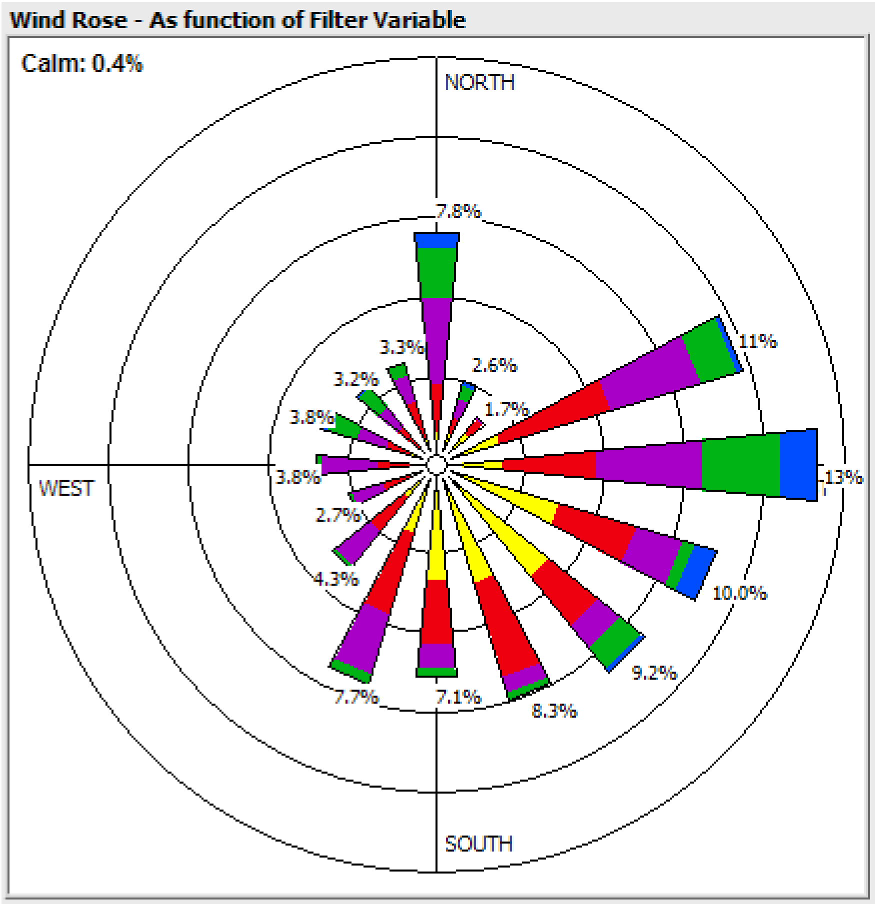


Figure 4: Wind Rose of North Aegean Sea (RAE)

- ❖ Offshore Wind Turbines which are compared in order to choose the most appropriate list of Images.

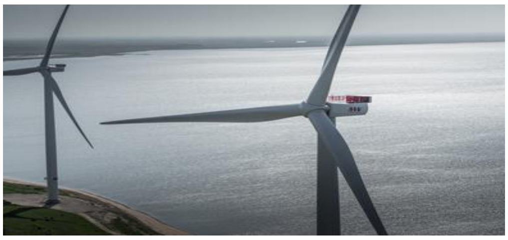
Adwen 135

GE Haliade 6MW

Ming Yang

Siemens Gamesa

Adwen D-180



Vestas MH1

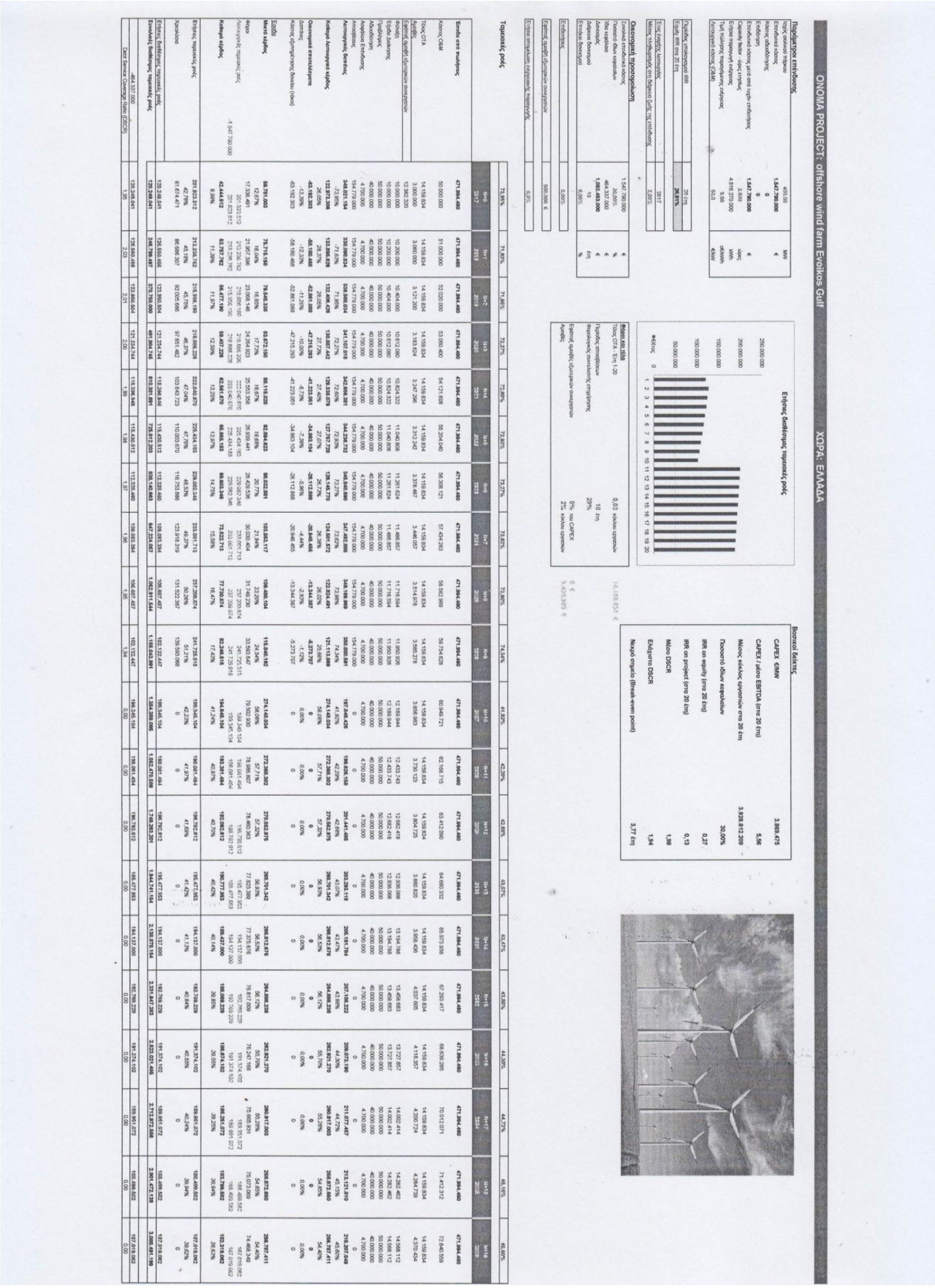


Figure 5: A Print Screen of the entire Financial analysis and Financial indicators

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