Master thesis

Analysis of the offshore Greek energy scene leading to potential sitting of and offshore wind park, policy framework creation for the Greek reality

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Abstract

Based on the actions that have been undertaken from the Greek government, this thesis tries to analyze the offshore wind scene of Greece. By following a methodology of past and present analysis, it tries to reach an analysis of where does currently this scene stands and tries to hypothesize future outcomes. Additionally, it tries to answer a relevant to the actions research question regarding the RETs in Greece so that it can focus specifically in offshore wind energy. This research question that fits perfectly the scope of this thesis is the following, “How realistic is the implementation of offshore wind projects to Greek waters and how could a potential social refusal could be mitigated?”. Some relevant questions to this can also be drawn, which they could help the reader understand the main motivational questions behind the creation of this paper:

- Is Greece’s wind potential enough to support major offshore wind projects?
- Why hasn’t Greece taken any initiatives until now?
- Towards what future is the energy scene heading?

From then on, this paper tries to analyze the Greek reality until the present years. Through the use of ArcGis software, the thesis takes the role of Greek government and tries to pinpoint the a potential area of development. Finally, it undertakes the task of partly designing a policy framework relevant to the needs of that Greek reality. Having in mind that offshore wind development might resume at Greece at some point, it tries to create a powerful tool for the implementation of such projects.

Chapter 1: Introduction

Producing and securing energy is a basic need for the survival of living organisms, wether this energy is in the form of food or heating energy. A modern country is no exception to this basic rule of survivability, considering a country as a living organism it tries to produce and secure energy for the purpose of providing it to its members. Energy security is an embodiment of this rule, as it represents the ease at which a country can provide energy to its citizens.

Although Greece is considered a developed country, its energy resources shows a fragile energy market. Greek energy sector is rather one sided as it is heavily based in the production of electricity from coal and burning of fossil fuels.

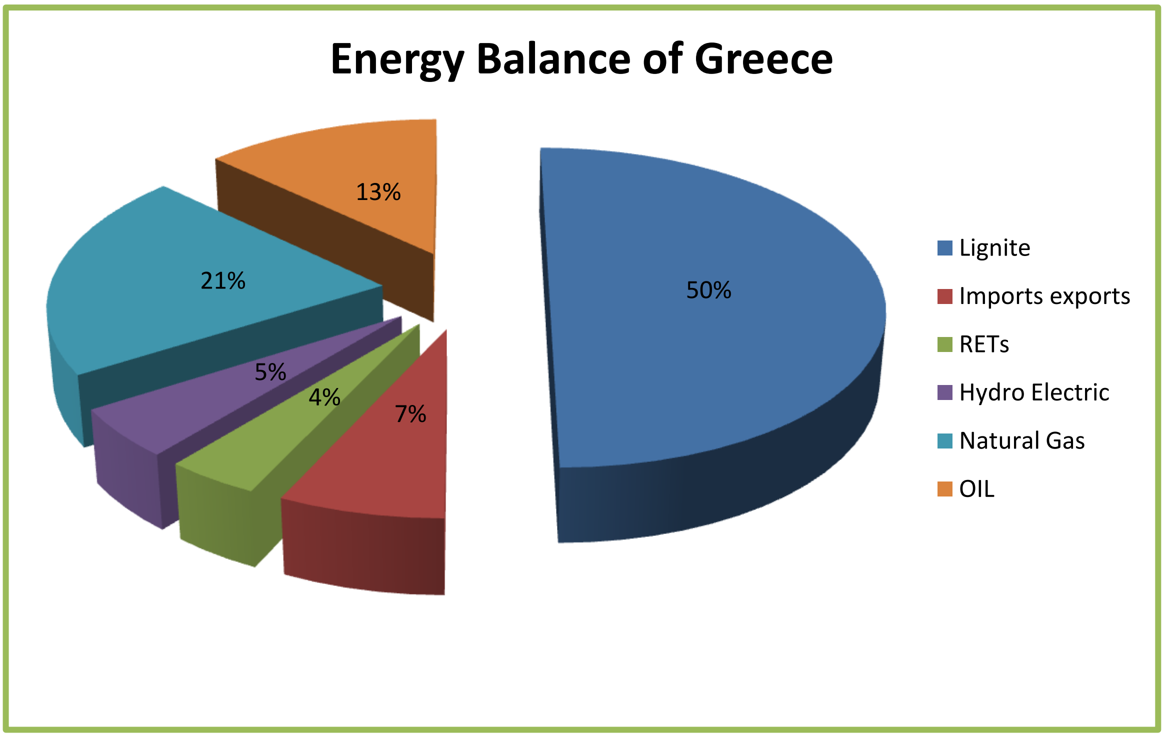

Figure 1 1: Energy Balance of Greece

Source: (Ageridis 2009)

As figure **1.1** indicates, the biggest portion of electricity is being covered by burning lignite. Regarding the Renewable Energy Technologies, Greece is a newcomer to both wind energy and of course to Photovoltaic. Furthermore, the high dependence in lignite, can be the reason for great fluctuations in prices of energy in Greece and as a result in reduced energy security. As mentioned by the Center for Renewable Energy Sources and Savings, from here on out CRES, one of the future targets of Greek energy policy will be the diversification of energy sources and including renewable energy source in the mix will help achieving this goal (CRES 2010).

Chapter 2: Conceptualization of the thesis

Diversification is not the only reason why Renewable Energy Technologies, henceforth RETs, are advantageous to be introduced in the energy market. Greece being a member state of the European Union has to comply with the targets set either by directives or protocols. In accordance to Kyoto protocol, EU signs in action the Directive 2009/28/EC inside which is mentioned: "The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change" (EUR-Lex 2009).

These directives were set in action partly to promote RETs construction throughout Europe and Greece is no exception (Greek Goverment Newspaper 2008). As it was stated formally by the Greek government in the year of 2008, the realization of those targets would be accompanied by the support of RETs which constitute a big portion of Greece's plans. This support would appear in various ways amongst which, was the reformation of the licensing procedure which at that point characterized by a lot of different authorities and bureaucracy, leading to a slow moving process. The reformation itself will be further analyzed in the upcoming chapters.

Greece of 2008 was preparing to accept RETs as an energy solution and although it was considering RETs as "clean" energy sources free of any emissions, it was not avoiding the fact that some environmental concerns exist alongside (Greek Goverment Newspaper 2008). But, through the use of environmental studies prior of any RET project, any implications could be avoided and that is what the licensing reformation was targeting. By changing its state of indifference, Greek government was hoping to have an active role in this procedure, get educated for each project taking place in the country and increase the safety of the environment and as a result ensure the public good and ease public opinion (Greek Goverment Newspaper 2008).

Although it is not stated by either the Greek government or any other authority relevant to the reformation, the final result of these changes would be an initial step to transform Greece's energy scene and it would be done in similar way as another pioneer country in the integration of RETs, Denmark. According to Danish Energy Agency, "The Danish Energy Agency is the authority responsible for the planning and erection of offshore wind turbines" (DEA on Wind turbines 2009). Additionally, the scope and role of DEA is to facilitate investments of offshore wind parks. In detail, it refers to "the overall official handling as a "one-stop-shop" which means that a project owner wishing to establish an offshore wind turbine project only has to deal with DEA" (DEA on Wind turbines 2009). Greek government wanted to achieve the same results and mimic an already successful paradigm, at least in this aspect, that of Denmark. A common approach build for any RET project, would simplify the procedure as a whole and any criteria taken into account would and could be evenly addressed.

Focusing back on the thesis at hand, in order to have a more focused scope for this project, a research question for which an answer is sought throughout the duration of this paper could be provided at this point. As it is implied earlier, this research question should be relevant to the actions taken regarding the RETs in Greece so that it can focus specifically in offshore wind energy. This research question that fits perfectly the scope of this thesis is the following, “How realistic is the implementation of offshore wind projects to Greek waters and how could a potential social refusal could be mitigated?”. Some relevant questions to this can also be drawn, which they could help the reader understand the main motivational questions behind the creation of this paper:

- Is Greece’s wind potential enough to support major offshore wind projects?
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As such the Greek reality which partly presented above and will be further analyzed later on, worked as a driving force to further investigate the relationship between the current Greek energy scene and RETs.

Chapter 2.1: Methodology

The methodology that is being followed for the creation of this thesis, can be characterized as a chronological analysis and relies in the fact that in order to analyze in depth the current situation of RETs in Greece and more specifically offshore wind energy, one has to look the past the present and speculate possible scenarios for the future. Under this framework, a chronological order is followed uniformly throughout this paper for the placement, writing and construction of the chapters and it is explained in the following figure.

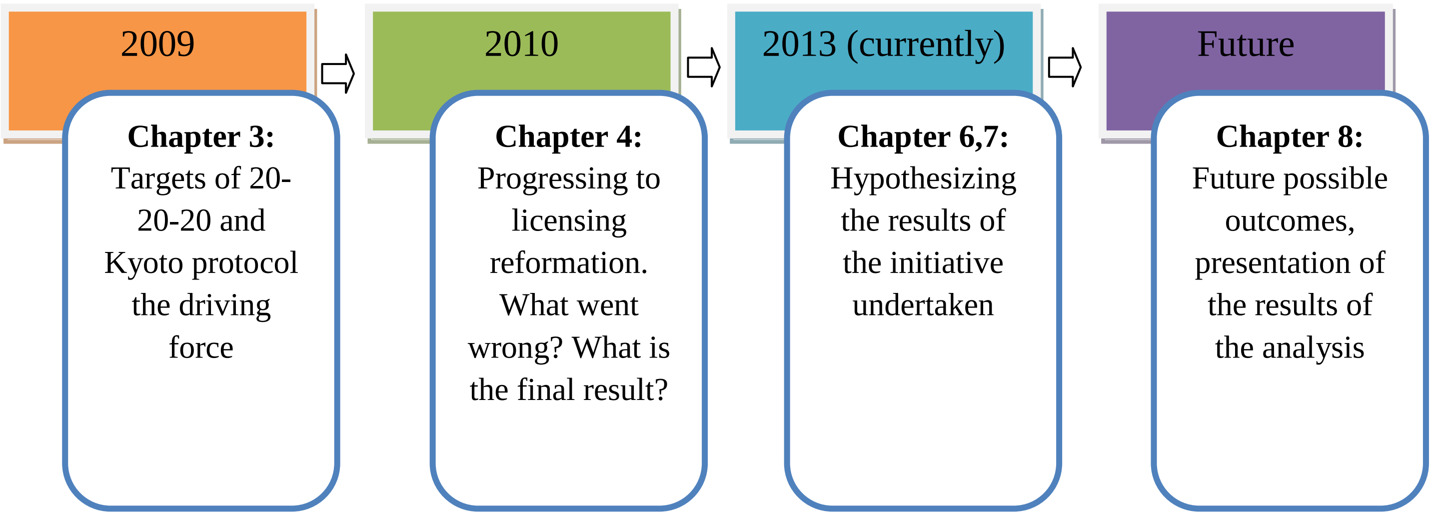

Figure 2 1: Presentation of the methodology followed and the way it was constructed

According to figure **2.1** above, starting at chapter 3 and more specifically in 2009 an analysis takes place regarding energy produced, by what technology mix and an analysis of the capacities and percentages at which the RETs were contributing at that period. This chapter focuses on the year 2009 as that is the year that a redefined directive of 20-20-20 comes into power and as such, the analysis present the findings of previous years along with future targets. The importance of presenting those targets lies on the fact that they were the main motive of the Greek government and the driving force for any actions that started at that period

Chapter 4 that follows, focuses in the year 2010 when the reformation of licensing procedure starts. The chapter is based mainly interviews conducted with some of the administrative authorities that were physically taking place in the reformation happening in that year and an engineering company that was present at the time, filling the role of an investment company which had at that period and still has until today applied for license for the construction of offshore wind park. This chapter can be partially seen as a semi actor analysis, as while it approaches the theme of reformation as subjectively as possible, it reveals some of the main actors at the energy scene of that period which are also still present until today.

Next up are chapters 6,7 (chapter 5 is a technology review) which chronologically are placed in 2013. With the use of the results taken from the reformation procedure, these two chapters, hypothesize a probable finalized result that the Greek government would have reached if it had proceed with the reformation. The study conducted in these chapters was planned to take place, as it will be further explained later on, but it never did. The study uses ArcGis software for the analysis as it is one of the most used software for spatial analysis and creation of maps. Further explanations on the way the study proceed, will be given in each of the chapters accordingly.

Finally, chapter 8 focuses in a possible implementation of a hypothetical project which takes place in the study area indicated at chapters **6,7**. Based on the fact that in a tourist based economy such as Greece, offshore wind projects are expected to be faced as possible threats to the status quo, chapter **8** undertakes once again the role of Greek government, also done in chapter **6,7**, and tries to mitigate a potential NIMBY public opinion in the local municipality while trying to suggest how this analysis could be used in possible situations in other sensitive areas with strong public lobbying.

Chapter 3: Energy analysis and current situation

As it was mentioned in the methodology, this chapter will focus on presenting the 20-20-20 targets and why they were thought off as the main driving force. As it was at that time stated by the Greek government, these national energy targets are to be used as a strong motive for the development of RETs. In addition, Greece will be taking a huge step towards energy security, by exploiting sustainable energy resources, while minimizing its dependency to imported fuels (2009/28/EC n.d.):

- Achievement of 20% increase in the participation of RETs to the gross capital energy production
- Achievement of 40% increase in the participation of RETs in gross electrical consumption
- Achievement of 20% increase in the participation of RETs in end use consumption for heating and cooling
- Achievement of 10% increase in the participation of RETs in end consumption of energy for transport

This directive constitutes a milestone for the energy scene in Greece as no later than October 4th 2009, the newly formed government took on the challenge of achieving the targets set forth. In addition to the above mentioned, Greek government was undergoing reformation changes such as "the establishment of a new Ministry for the Environment, Energy and Climate Change (hence forth MEECC)" (N. Charalambidis, M. Christou. et. al. 2009), that were aiming in facilitating licensing procedures for RETs projects and meanwhile have an increased responsibility on the outcomes of all of the activities that would potentially happen, by caring about the natural biodiversity of Greece by safeguarding and analyzing each and every project in regard to its side effects and end results in general (N. Charalambidis, M. Christou. et. al. 2009).

Other than the government itself, partly responsible for the changes that were taking place at that time in the energy scene was Ms. Tina Birbili, new minister of MEEC. The targets set forth by the directive of 20-20-20, were considered not just as an obligation that Greece had to fulfill, but also, as an opportunity at that time, to strengthen an unstable economy by introducing new investments along with new opportunities for work, something considered highly important at that point and as it turned out also highly important later on until today. According to the committee responsible of overlooking the achievement of the targets of 20-20-20 that was put together from minister Birbili, "the triple targets of 20-20-20 is estimated that they will boost the competitiveness of the economy and attract investment capital and technical knowhow" (N. Charalambidis, M. Christou. et. al. 2009). Criticizing though this responsibility undertaken, it is worth mentioning that MEECC at that point was focusing more in attracting investments than supporting the boosting of efficiency and minimizing the losses of the past energy systems. The only initiative that was interlinked with efficiency at that period, was referring only to house owners in the form of partly public funded and of improved efficiency new buildings or improvements in the old ones.

Supposedly, the targets would be met by increasing the share of RETs in gross electricity production and consumption, energy consumption for heating and cooling and transport. In order to understand what each of these represent, a definition is going to be presented before venturing further on.

According to European Commission gross energy consumption is the sum of (Nikolaos Roubanis, Carola Dahlstrom et.al. 2010):

- Final energy consumption to all sectors of the economy including industry, transport, households, services etc.
- Consumption of electricity for the purpose of heat generation
- Loses accumulated during transmission and finally distribution

The electricity produced from RETs is the one produced by such technologies excluding hydro pumps. Because this paper will deal with wind energy and more specifically offshore wind energy, the definitions regarding electricity produced from RETs used in heating and cooling is focusing mainly on the electricity used in order to power devices as Air conditioning. In Greece, Air conditioning units are the main way of cooling during the warm months of spring and summer and also it is used from many households during the winter period. Finally, regarding transport the only immediate link with the potential offshore wind energy would be the use of electric cars for the charge of which a fraction of the electricity used would be generated by offshore wind projects.

Regarding higher energy penetration of RETs in gross energy mix of Greece, there are several barriers that must be surpassed in order to reach the goal, for example the fact that many islands remain until today unconnected to the main grid of Greece is one of those barriers that is going to be analyzed further more in the next chapters. Amongst the RETs that were chosen, as those that have high potential and will be further developed in order to meet the targets of 20-20-20, wind has a distinct place as it is stated by the committee.

Figure **3.1** illustrates the percentage of the share of RETs in the total electricity generation of Greece. The share seems to increase steadily throughout the years 2004 until 2010.

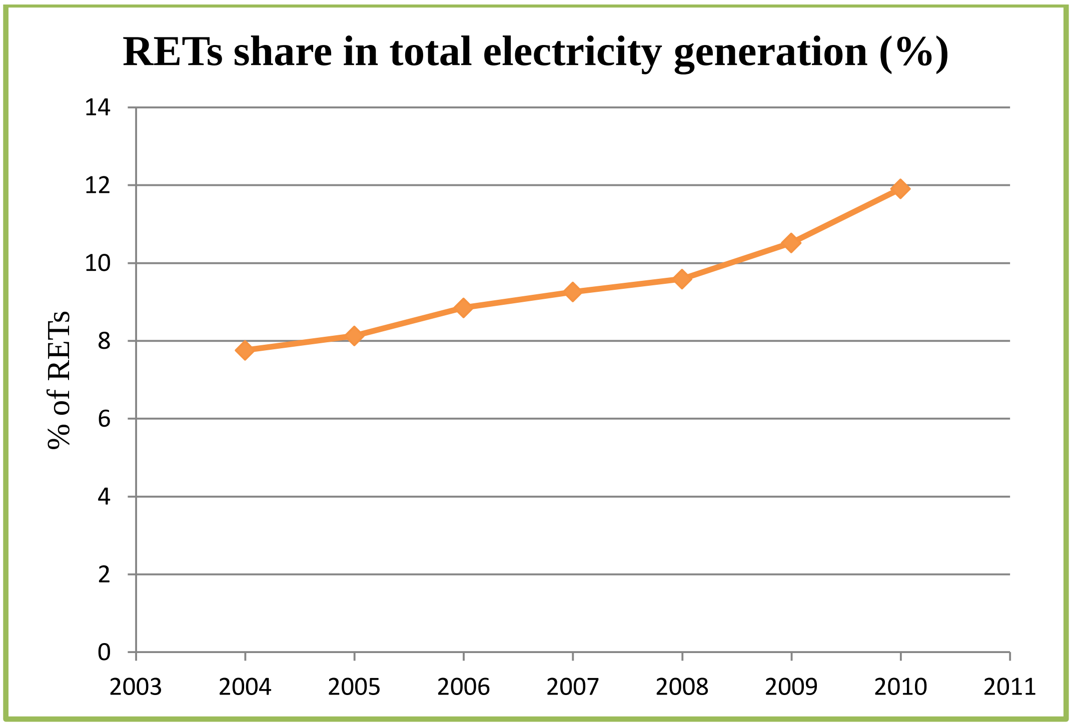

Figure 3 1: RETs share in total electricity generation

Source: (Eurostat 2010)

Examining the data provided for the above figure in more detail, the rate at which the share of RETs was increasing can be easily calculated. By taking the share of RETs for year 2005 and subtracting from that the share of year 2004 it results in the Increase Rate (IR) of that year.:

- $2005_{\%}$-$2004_{\%}$=$IR_{(2005)}$

The next figure is the result of the above mentioned calculation, showing the IR of the share of RETs in energy production.

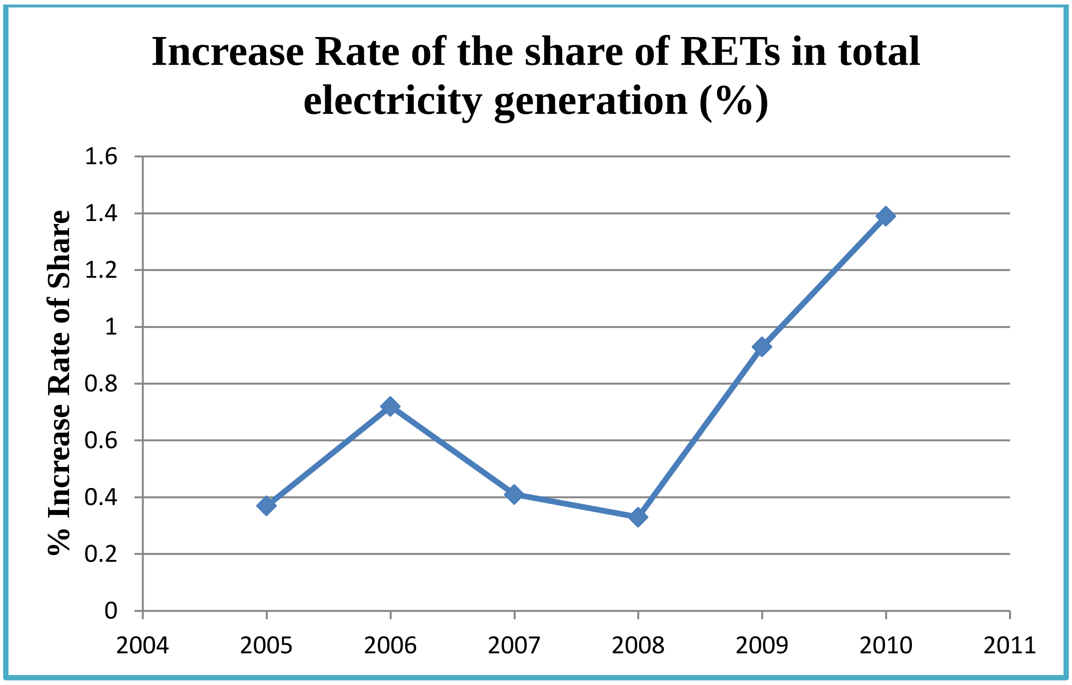

Figure 3 2: Increase Rate of the share of RETs in total electricity generation (%)

Figure 3.2: (Eurostat 2010)

As it is presented, the IR stayed positive for that period (2005-2010). As shown in figure **3.2** above, the highest rate at which the share is increased is reached in the year 2010 and more specifically it reaches a percentage of 1,39%. This is probably due to the fact that during those years and as early as 2000 there is major photovoltaic and wind turbine installation taking place in Greece. The rest of the technologies that are within the RETs share at the year of 2010 are Biomass and waste, Geothermal energy, Hydropower, solar energy and wind power.

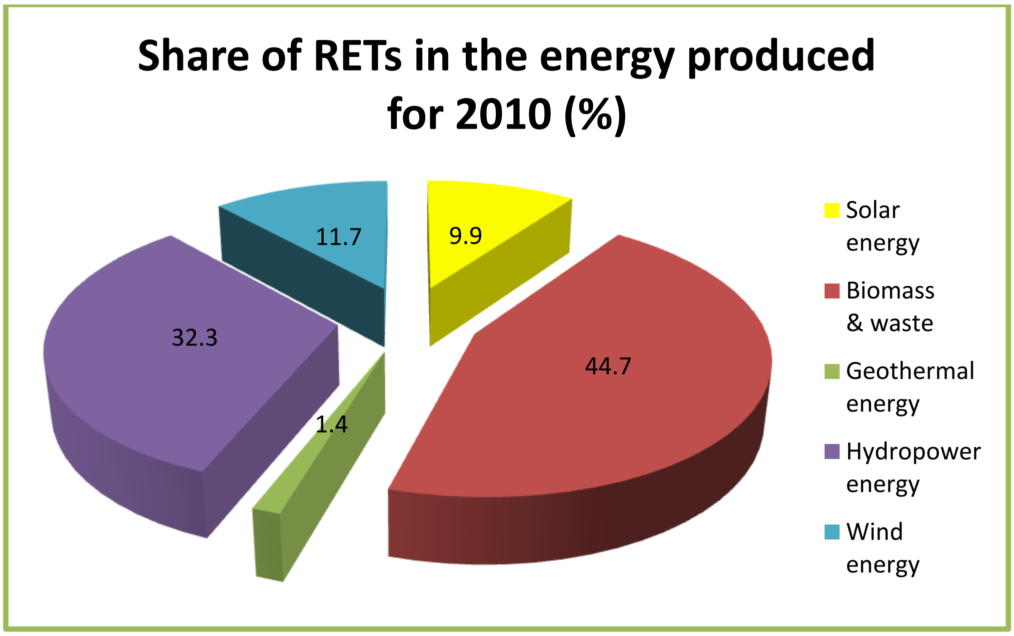

Figure 3 3: Share of RETs in the energy produced for 2010 (%)

Source: (Eurostat 2010)

From all of the RETs that appear in figure **3.3**, it is obvious that the biggest share goes at biomass and waste followed by hydropower. Although their share is pretty big compared to solar and wind energy, according to MEEC and the committee the amount of investment planned for wind and solar was way higher from that for the rest of RETs, "7,5 GW for wind energy 2,2 GW for PVs, 250 MW for CSP plants, 120 MW of geothermal energy, 250 MW of bio-energy installations, 250 MW of small hydro plants, 350 MW of large hydro plants and 880 MW of pumped storage plants" (N. Charalambidis, M. Christou. et. al. 2009). These capacities were part of the overall planned capacities to be installed in order to achieve the targets of 20-20-20. As done for member states, at that period Greece had provided the national renewable energy action plans to European Commission, accounting for the future plans and targets of increasing the overall integration of RETs in the energy mix (N. Charalambidis, M. Christou. et. al. 2009).

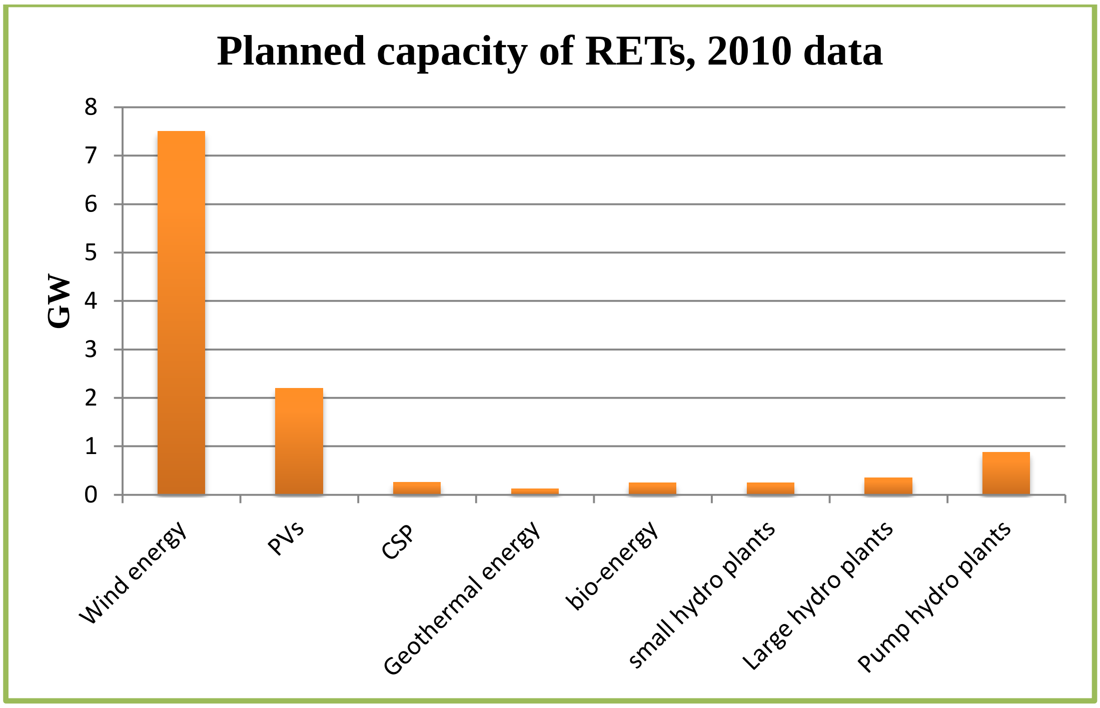

Figure 3 4: Planned capacity of RETs, 2010 Data

Source: (N. Charalambidis, M. Christou. et. al. 2009)

Due to the high potential of wind energy in Greece, the hypothetical future mix of the country would be partially supported by wind energy something that is shown in figure **3.4**. For that reason, the government and more specifically the minister of MEEC, was planning to reform the procedure by which investment engineering companies would deal with the appropriate licensing and thus facilitate them. Although this plan started for a good cause, the results that it finally achieved were and still are doubted by many and it will be further analyzed in the following chapters.

In addition, the capacities that are mentioned in the above figure **3.4**, were based in actual data and projections which at that point and period seemed feasible. Thus, at the year 2010 MEEC and the committee had specifically written that for the next years Greece would follow a period of economic growth with average rates of 2,7% (N. Charalambidis, M. Christou. et. al. 2009). This would evidently bring forth an increase in energy demand, similar to that of the economic growth, which equated to some specific numbers of installed capacities of RETs in order to succeed in meeting the targets of 20-20-20. As such, the capacities that were presented earlier represent the expectations of Greek government at the time. Of course, there were other more optimistic scenarios describing an economy that would grow faster and RETs would play their role by having bigger shares but as it is well known there is no point in describing them after the recession. Even the baseline scenario that presented average growth of 2,7% is nowadays very unrealistic to happen, it is only used at this point and presented in the figure that follows to show together with figure **3.4**(above) the preference of Greek economy to invest in wind energy.

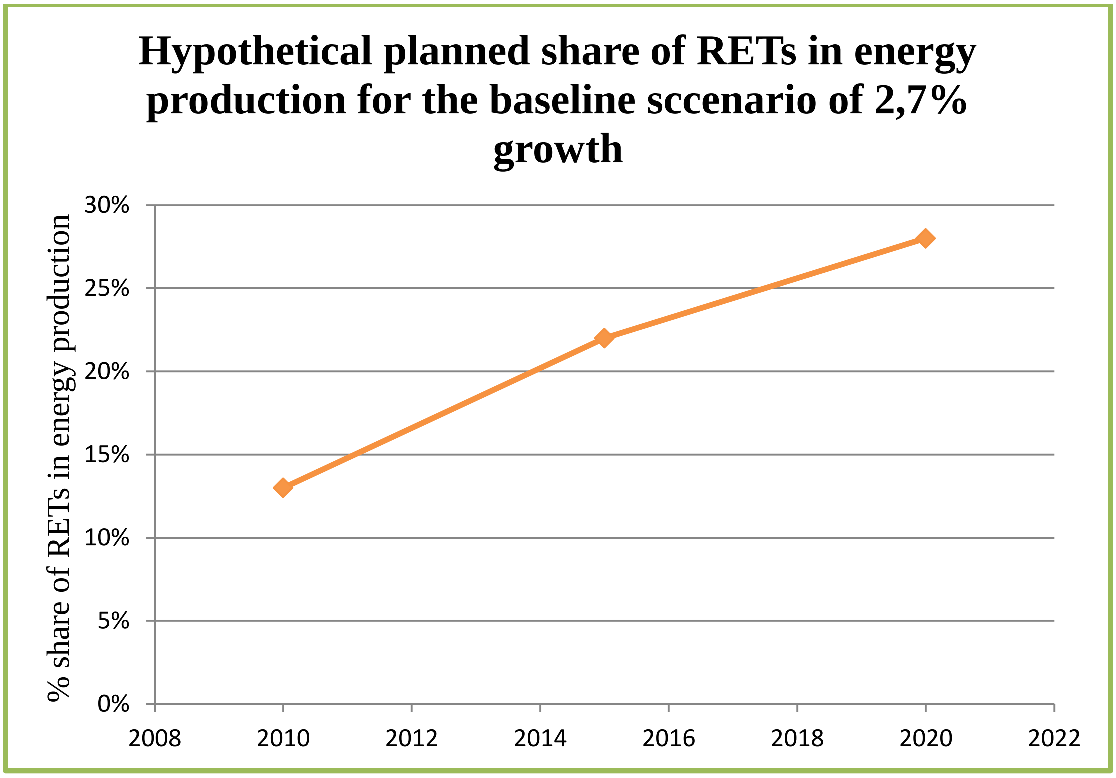

Figure 3 5: Hypothetical planned share of RETs in energy production for the baseline scenario of 2.7% growth

Source: (N. Charalambidis, M. Christou. et. al. 2009)

Although this scenario was not considered so optimistic as already mentioned, Greece would still be able to meet the targets of 20-20-20 as projected in year 2020 when the share of RETs in total energy production reaches 28% with wind energy on top of the list. An estimate of the final amount of energy needed to be covered in the year 2020, partly from the capacities of RETs discussed earlier, was close to 68 TWh according to National Renewable Energy Action Plan of Greece (NREAP) (N. Charalambidis, M. Christou. et. al. 2009).

All the installations would have taken place until the year 2020, but, things have changed as economic recession struck Europe and subsequently Greece. The steady raise of RETs share in the electricity also stopped alongside with any new investments shortly after year 2011. By now, it is imminent for someone to assume that Greece is not going to meet the targets of 20-20-20 set forth by the directive. According to European Commission, which stated in 2012, “Greece is one of the five countries that have fallen behind and they are not expected to meet the targets” (Europe2020 2012).

Regarding RETs share in final energy consumption, it depicts the rate at which energy from RETs penetrate the net consumption of the end users. For the same reason that was earlier explained, economic recession, this share has remained stagnant along with the capacity of installed RETs as both capacity and share in final consumption of RETs are interconnected, the reason being the long contracts signed between renewable energy producers and the national energy company of Greece which until recently was solely public owned.

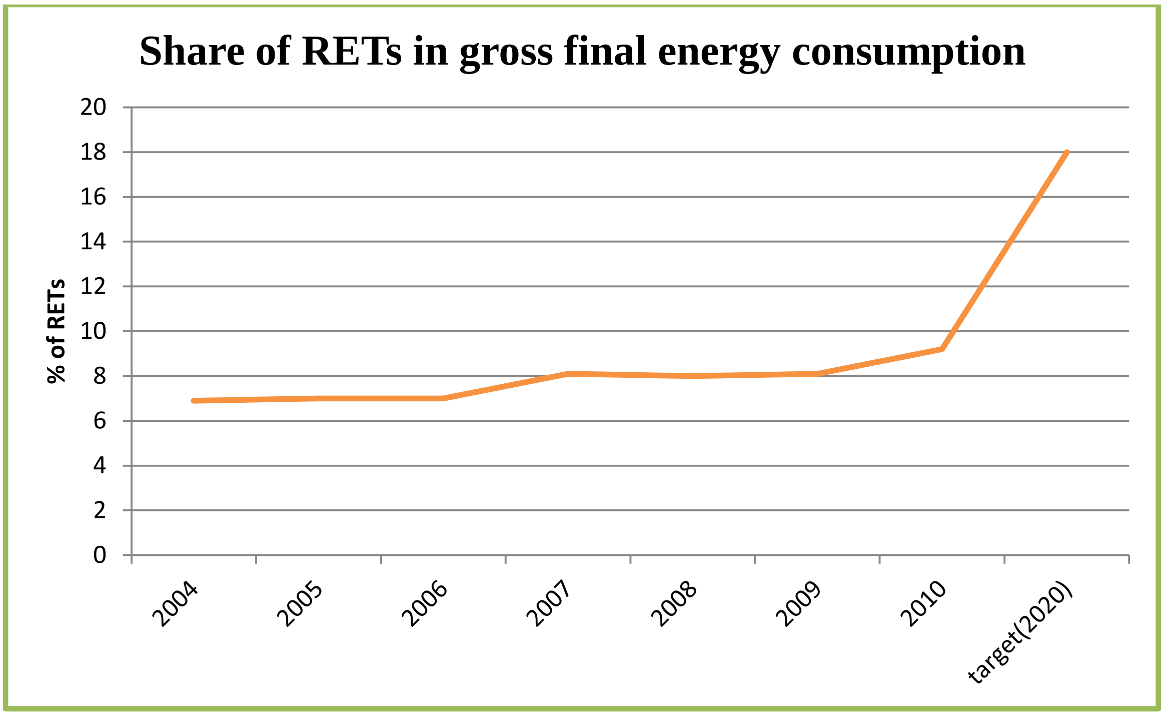

Figure 3 6: Share of RETs in gross final energy consumption

Source: (Eurostat 2010)

Figure **3.5** presents the share of RETs in the gross final energy consumption. As analyzed above for the electricity generation, the consumption of electricity in general would have probably grown at similar rate if it was not for the recession. Until year the 2010, the penetration of RETs in consumption was presenting an increase and the steep incline towards the end of the diagram represent the number which the share had to reach in order to comply with the 20-20-20 targets.

Chapter 4: current energy scene, what went wrong?

Chronologically, this chapter will focus in the analysis of the energy scene during the period of 2010 until today. In regard to what was discussed earlier in chapter 3, which focused on the period up until the year 2010, it was said that an effort of reforming the licensing stage in order to facilitate engineering and investment companies, was undertaken by the minister of MEECC Tina Birbili.

An effort was being made so that RETs could be established as a priority for Greek government, as also stated in one of the interviews of the minister of MEECC, "we are convinced that investing in renewable, and clean energy technologies in general, is the most efficient way to achieve our medium and longer term national targets regarding energy, environmental protection and economic growth" (Azau s., et al. EWEA magazine volume 29/N. 5 2010).

Regarding the social impact that the introduction of RETs would have to the unaware citizens, it seemed straightforward that MEECC was planning to introduce the whole concept as a way to achieve environmental targets and avoid further taxation set forth by directives for CO_2 emissions, educate public about strengthening local economy by the creation of jobs and aim for energy independence as it was highlighted by the minister above. Also, It was hoped that by expediting their integration in the energy market, the new reformations would help the public opinion to overcome the well known predisposition of NIMBY (not in my back yard), by lowering electricity bills for habitats living in the vicinity of such projects and with the help of similar incentives (Azau s., et al. EWEA magazine volume 29/N. 5 2010).

In detail, the rest of this chapter analyses how the licensing procedure was prior to the year 2010, what could the changes have accomplished and what they finally did. The following facts are based on interviews taken from experienced and well educated on the matter people, working in several different Greek private or public organizations. Just to name a few, Center of Renewable Energy Sources (CRES), Hellenic Center of Marine Research, Terna engineering and investment company. Finally, before venturing further on it is very important to connect this chapter with the rest of the paper and this will be shown by the result of the analysis of the energy scene, which will hopefully show why no major wind energy projects have not taken place in Greece yet and why the specific case study of this paper was chosen.

Chapter 4.1: Licensing stage reformation

The offshore wind energy projects of that period were still at their infancy, the main focus was at that time to gain licensing permissions so that large investment engineering companies could commence their construction phase. Individual companies had several roles to fulfill in order to gain license over a specific area and start building:

- Pinpoint the desired location through analyzing the potentiality of wind speed and accessibility and whatever else they deemed as advantageous for their specific case
- Conduct an environmental study and forward that study to Regulatory Authority for Energy (RAE) where some of the environmental aspects of the project would be studied. In case of environmental barriers appearing, licensing would be postponed or denied
- Each individual company had to undertake the task of separately cooperating with all the involved public or private entities, before utilizing the location pointed so that the wind turbine would not interfere with any other land uses. Some examples of this particular case would constitute, contacting archeological authorities in case there were any archeological remnants such as ship wrecks as to gain permission, or contact airports and military services regarding the visual disturbance as to find an optimum area of use

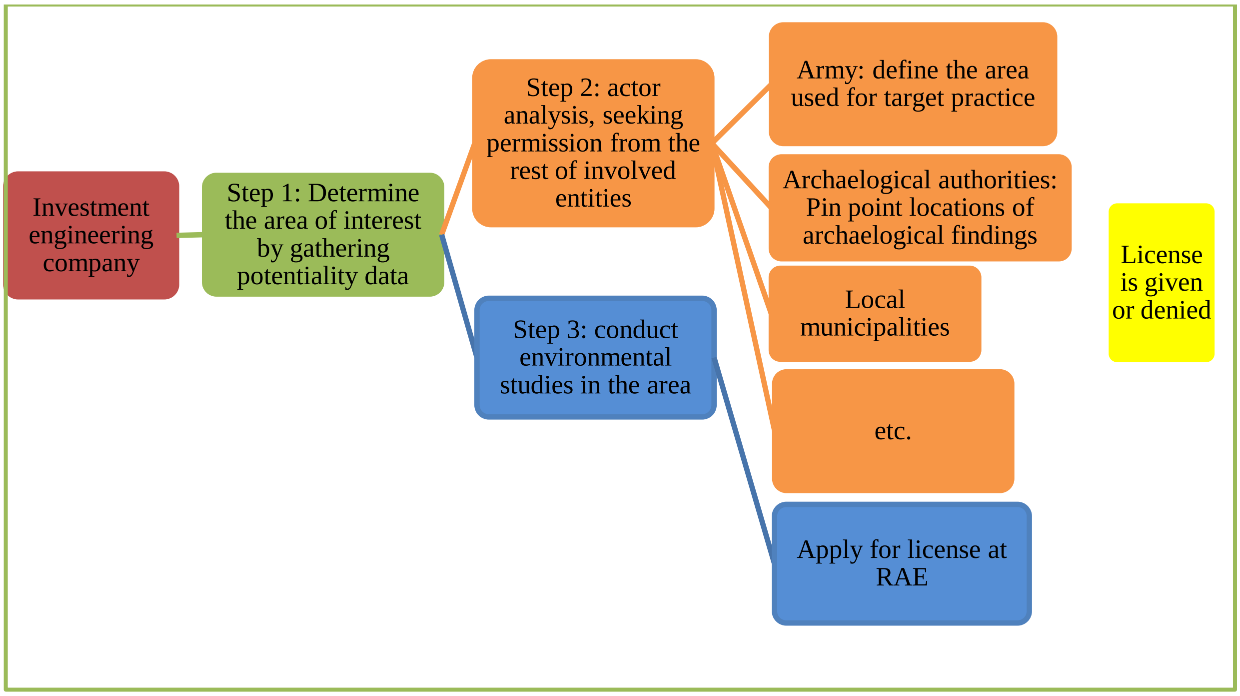

Figure 4 1: Licensing procedure prior to reformation

As it is seen in detail at figure **4.1**, the interest of the company for any investment has to be translated to 3 different initial steps for the period before 2010. As done also with similar projects, the initial interest derives from analyzing the potentiality of the area. Shortly after and upon agreement that this is a suitable area, the investment company had the leading role of reaching any kind of agreements or gaining permissions with the rest of the actors in the vicinity of the area of interest. Step 3 represent another role that the investment company had to fulfill in order to gain license and that was to conduct an initial environmental study which would render wether there are environmental barriers or not and finally seek the license of RAE, in which the environmental study itself was being forwarded to.

What is rather obvious and in the same time odd, is that although, any kind of company that was looking to invest its money to the energy scene of Greece at that period was looking to do it as cost effectively as possible, this whole procedure could only be characterized as money and time consuming, resulting in repelling investments away. A simple example of the fact is that by the time that the license would be given or denied, the interested company would have to cover for a lot of costs such as the environmental study of the area and also spent a lot of time in a project that in the end might be denied resulting in losses. All of the above would usually take between 4 and 6 years to be completed and this was one of the main aspects that MEECC wanted to change by reforming the licensing stage. Last but not least, the licensing procedure before the year 2010 was executed every time a company wanted to apply for a license in a new area.

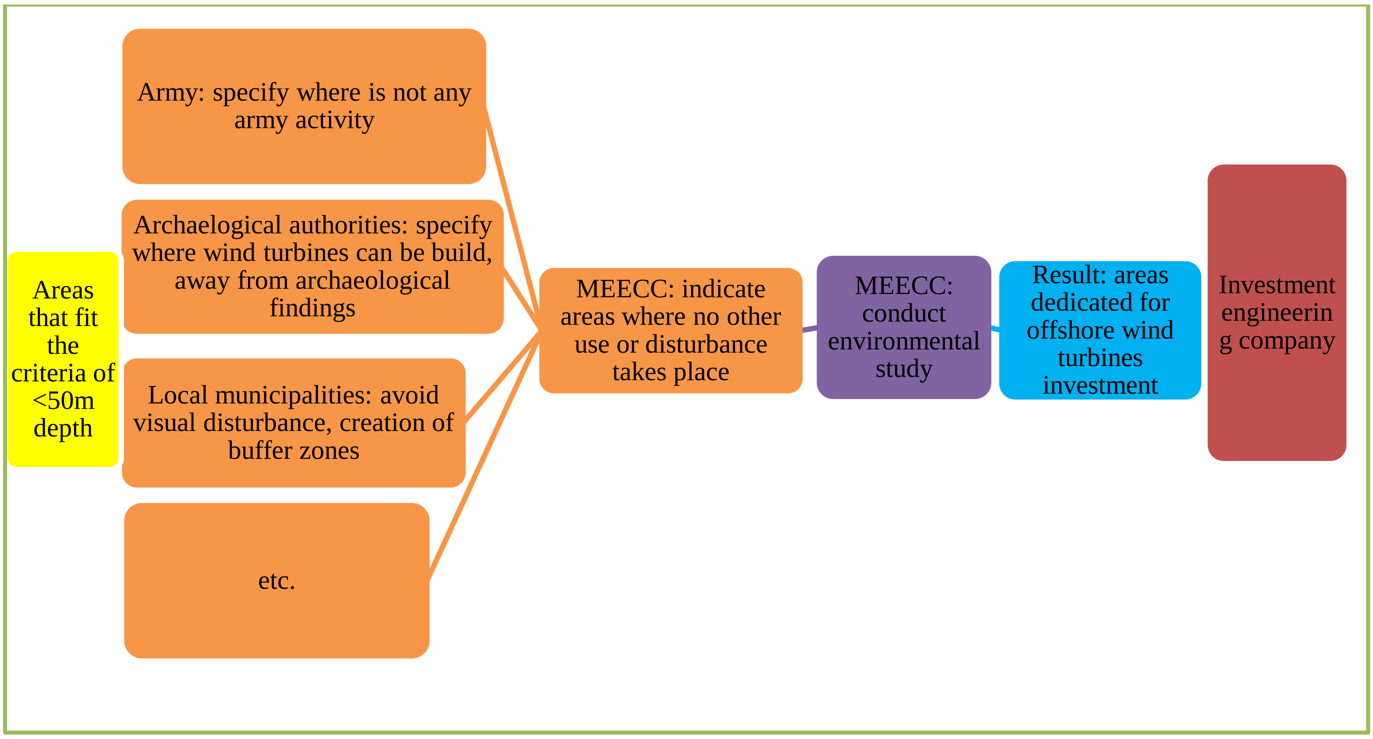

Figure 4 2: Licensing procedure post reformation

After the reformation had taken place, the new driving force would have been the state instead of investment companies, which would only be the end user of the area specified for wind turbine construction. To begin with, the illustrated procedure in figure **4.2** would take place only one time, as MEECC was aiming at that point to indicate all the potential areas of future offshore wind development at once. After an initial analysis for shallow water areas fitting the criteria of <50m, MEECC would forward those areas to all local authorities such as the army, airports, archaeological authorities and would ask from them to specify their activities or barriers in the vicinity. This would result in free of any other activities areas, while complying with the criteria of <50 meters needed for the construction of offshore wind turbine foundations.

Next step would be for MEECC to conduct an environmental study in those areas so that to be sure that no disturbance in endangered species of animals or plants would take place during the construction and throughout the lifetime of each project. Finally, MEECC would showcase these dedicated for wind turbine construction areas by organizing an auction competition open to all investment companies, with which it would yield the rights of construction to the highest bidder Supposedly, the reformation would minimize the whole procedure from 4 to 6 years to only 1,5 years and would greatly facilitate any company wanting to invest in offshore wind energy in Greece (Azau s., et al. EWEA magazine volume 29/N. 5 2010).

Although this reformation was regarded really promising and would help in kick starting offshore wind energy investments, things got rather complicated instead. Between 6th and 20th of July of 2010, MEECC made the public aware about the initial choice of areas for offshore wind energy development. The chosen areas were free of any other land use and other activities linked with public or private entities, also, they were fitting the criteria of shallow water depth, less than 50 meters (MEECC 2010). Because the procedure was being controlled by the state, it was thought that the contact between authorities such as local municipalities or the archaeological authority would be smoother. Unfortunately, things were different as many of the local municipalities although initially showed interest for the procedure, specifically for visual disturbance, later on they removed themselves completely from the procedure.

Nonetheless, MEECC was planning ahead and as said earlier, the next step would be to conduct environmental studies. At that point, the slow moving state along with the rather low budget that MEECC had to operate with at that period, resulted in the freezing of the whole procedure. Taking into consideration that the only result was applying some initial criteria in these initial areas, what this reformation has managed to do was to further delay the offshore wind energy scene which still in its infancy had not seen any real activities other than seeking license for construction. Even at that moment, any investment company that still wanted to go through with any area indicated from MEECC, would still have to deal with the environmental studies resulting in spending money for something that MEECC had committed on doing. In other words there was little progress made while delaying foreign or domestic investments.

In the end, it is worth mentioning that before the reformation started, some initial applications for licensing had already been submitted in RAE, but, immediately afterwards they got frozen because in case that the areas selected arbitrarily by investment companies were different than the ones indicated by MEECC and nevertheless got licensed, it would seem that the role of MEECC would contradict with what it was trying to achieve.

Nowadays and according to one of the interviews performed with TERNA (engineering company), the private funds dedicated for offshore wind development are no longer available because of the recession. Furthermore, the paradox of the situation is that some offshore projects that were thought of at that period are still at licensing stage and may as well at some point be granted license. Unfortunately, at that moment it will not mean that any investments will take place due to lack of capital. These are the main reasons why the results of the reformation that took place are doubted by many people wether they affiliate with private companies or public authorities.

Chapter 5: Technology review

This part will focus on explaining some of the parts that consist an offshore wind turbine. Although pioneer countries at wind energy such as Denmark had tackled pilot projects as early as 1991, for countries such as Greece and in general those countries surrounding Mediterranean, things are rather different as procedures for the construction and connection of offshore wind farms has not yet started. As such, a rather new technology has a lot of room to grow in those areas as expected. Regarding the evolution of offshore wind turbines, their size and output will increase in the future and so each and every one of the components consisting a wind turbine will also change.

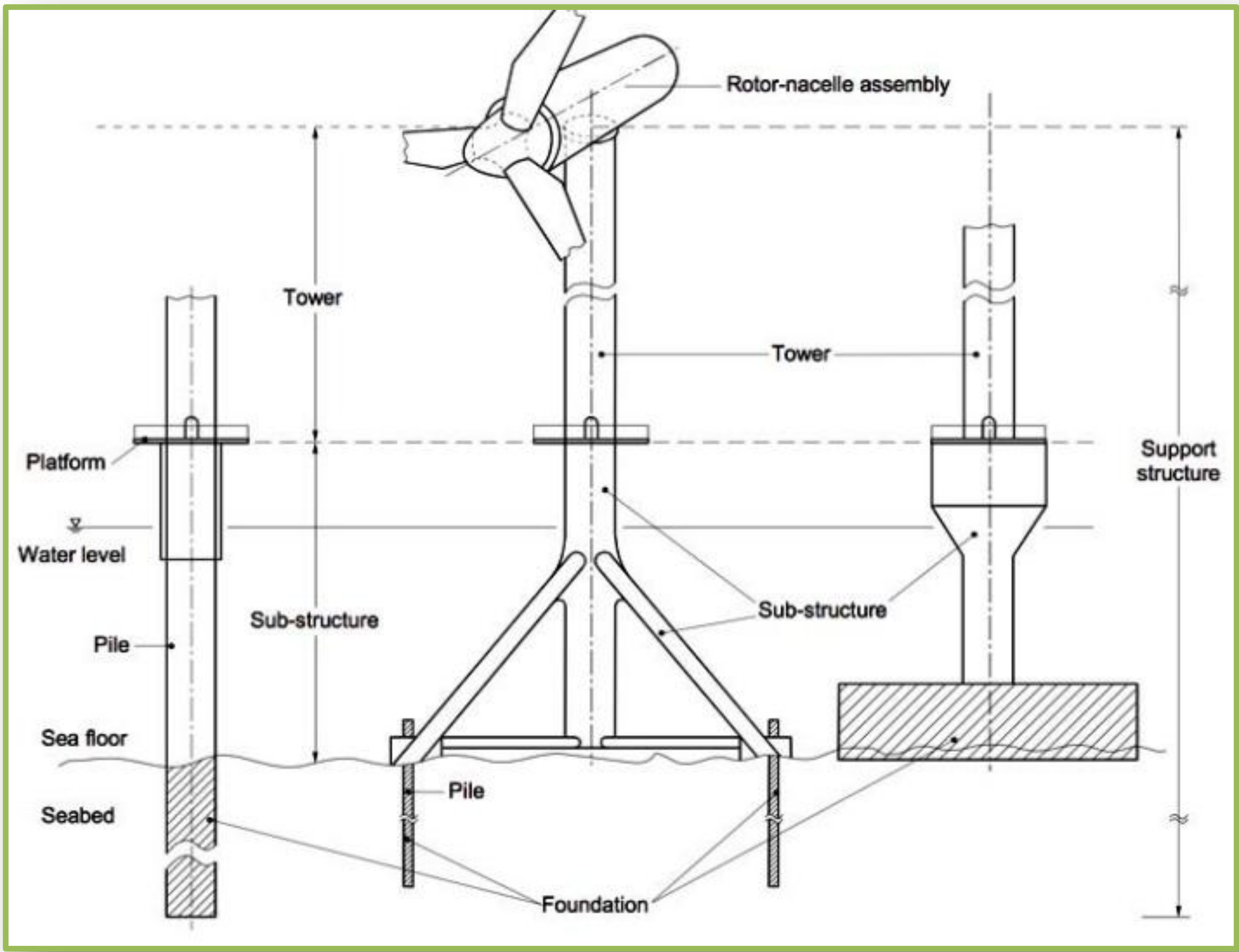

Figure 5 1: Components consisting an offshore wind turbine

Source: (IEC 2009)

The current components that consist a wind turbine can be seen above. From top to bottom, nacelle is where the gearbox, drive shaft, land generator is located and sits atop the main body of the wind turbine which is also called support structure. The rest of its main body which is above sea level is called tower which also has mounted in its body the platform which is dedicated for human activities. Below sea level as seen in the figure 5.1**,** lies the sub structure of the wind turbine which ends up on top of the seabed where foundations come in place. Regarding the sub structure and the foundations, the way they are constructed varies depending from water depth, wave heights, currents and soil properties and last but not least from wind speed (Smadjia 2013).

Chapter 5.1.1: Foundations

According to onsite experiences and pilot projects of many engineering companies, there has been a common understating of a maximum water depth for each specific kind of foundation that exist. Accordingly and from shallow waters to deeper, first off and for depths of up to 10 meters, although recently have been used even deeper, the foundations best suited are gravity based. From 10 to 30 meters the best known solution and maybe the most wide spread is the monopile foundation, and from 30 meters till 80 meters there are the conventional steel jacket foundations and tripile, tripod structures.

Mono pile

Figure 5 2: Monopile foundation

Source: (Engineer 2012)

Monopile structures are rather advantageous compared to the rest of the foundations mainly due to its simplicity. Its appropriateness, is also attributed to the fact that these kind of structures were used in many pilot projects as in an early stage, the industry had the approach of trial and error in shallow waters before progressing to deeper waters were structures had to be more complex, for that reason monopile structures met this target by being simple to construct and rather cost efficient. Specifically, "the giant steel pipe is by far the most popular support structure in the world, 1923 of the worlds 2688 offshore wind turbines used monopiles for support at the of 2012" (LORC 2011).

The idea behind this structure is rather simple, a long steel pipe which when installed extends up to 40 meters beneath the ocean floor (Smadjia 2013). For depths more than those described, monopile foundations had to be disproportionally large in size and so, their use is not sought after. The way these structures are installed is widely known and used also from oil and gas industries, they are hammered into position by using hydraulic hammers. The seabed does not require any specific preparations for the installment of a monopile foundation, but, at specific sites where sea bed is characterized by the existence of large boulders monopile foundations are not appropriate (Smadjia 2013).

Investment costs

Although it is believed that due to the simplicity of its construction monopile has low cost of production (Smadjia 2013), opinions from engineering companies seem to differ. Production costs of prefabricated concrete foundations are four to five times lower per ton from steel monopiles (Ballast Nedam 2004).

Drawbacks

Considering that most of the projects at Mediterranean sea are pilot projects, most of the investment and construction that is going to take place as a first stage is probably going to be in shallow waters and as such, it is safe to assume that monopile foundations may be used. Defining and planning for some of the drawbacks of these structures is highly important.

First and foremost, during installment of monopile foundations the banging noise being created by the hydraulic hammer is alarming and dangerous for marine life. Due to the physical properties of water (high density and low compressibility), sound waves travel in greater distances and through reflection from both seabed and sea surface they can be easily broadcasted at dangerous levels as far as 500 meters from site (OCEANWISE#4 2012). At that distance "sound level is 174 dB re 1mPa which cause temporary hearing loss for marine mammals and repeated exposure can cause permanent damage" (OCEANWISE#4 2012). In conclusion, measures to mitigate noise have to be taken as Mediterranean sea roams with marine mammals such as dolphins.

Another major disadvantage of monopile foundation is the fact that it becomes unstable to be used for deeper waters, more than 25 meters (Athanasia Arapogianni et. al., [Wind in our Sails, EWEA] 2011). Due to the consistency of sea floor, which is sand and silt at depths up to the 40 meter point, and due to currents and waves, it makes the turbine prominent to risks of what is known as "scouring". It is the phenomenon of "washing away" the deposits around the base of the monopile foundation something that results in very unstable structure prone to the hydraulic pressures and loads (Dixen 2012).

Jacket

Figure 5 3: Jacket foundation

Source: (Engineer 2012)

Gas and oil industries have been using jacket foundations for many years now to support their rigs at depths more than 100 meters. When pioneer engineering companies sought for a solution other the monopile foundation in order to take advantage of greater wind speeds at deeper waters, they turned into jacket foundations as an alternative and thus the technology entered the sector.

This leap was firstly taken by an engineering company named Talisman Energy and the project was located off the east coast of Scotland adjacent to the Beatrice oilfield, taking the same name. This deep water pilot project went online at the end of summer of 2007, having installed two wind turbines on top of jacket foundations of a capacity of 5 MW at depths of around 45 meters and initial cost of 41 million euro (Beatrice 2007).

In detail, jacket foundation is an A-shaped structure made up of three or four steel legs which are connected through steel bracings welded in place. The whole structure is considered to withstand bigger hydraulic pressures by having a wider contact with the seabed thus strengthening it against waves currents and high wind speeds (Smadjia 2013) (LORC 2011). One concern though of this foundation type is the fact that between bracings and steel legs there are many welded points located, which can be considered as the weak point in terms of being parts of a load bearing structure and as a result can be damaged (LORC 2011).

Unlike the monopile which needs no preparation of the seabed so that it can be installed, jacket foundation is installed with usually two distinct ways called post-pilling and pre-pilling and need preparation at seabed level before the installation of turbine takes place. Thus, jacket foundation is a hybrid technology taking advantage of both the A-shaped structure and the use of piles to reach higher stability.

The terms post and pre-pilling refer to the actual time that the piles are combined with the rest of the structure. Starting with the most traditional method of the two, post-piling takes place after the jacket has been set to the seabed. Then, the piles are being vibrated or hammered to the seabed through the "sleeves", which are short steel tubes connected to each one of the jacket's legs. It is considered a more dated method to be used for the installation of wind farms in contrast to oil and gas industry as "oil and gas industry typically requires installation of a singles structure, whereas wind farms require installation of many similar structures" (LORC 2011).

On the other hand, pre-piling is done prior the jacket foundation is set to the seabed. This is done by using a smaller template which is used as a smaller base in which piles are being hammered in each side. After this procedure has finished, the jacket is being laid on top of the template using the piles as legs and finally combined into one structure (LORC 2011).

Investment costs

Considering that jacket foundation is bigger and more complex structure than the simple monopile foundation, it is only logical to assume that the use of bigger portions of steel will result in much higher production costs for this type of foundation. In fact, "the cost of producing steel structures like jacket-tripod foundations can be three times greater than the steel monopiles" (Ballast Nedam 2004).

In addition, investment costs can also vary depending on which method of piling is used each time. The most expensive of the two might be considered the post-piling, as during the installment of piles in the legs, the jacket must be hold in place and be balanced. To do so, "the expensive large vessels have to spend more time with each jacket" (LORC 2011). Pre-piling makes use of smaller vehicles to install the template thus, saving money by not using these large vessels as much. Also, the use of bigger amounts of steel has to be considered in connection to post-piling, as the sleeves alone can weigh as much as 160 tones, rending pre-piling more cost efficient (LORC 2011).

Drawbacks

One of the most stand out drawbacks of this design is the structure itself and more specifically, the steel bracings used in order to connect the legs of the jacket. These are welded in place and that fact alone indicate not only the weakness of the structure as described earlier, but also, the large amount of man hours needed to weld them in place (LORC 2011).

In contrast to the above, recent studies are showing great potential of the newly introduced laser welding practice in the field. Unlike industries that already use laser welding to weld plates with thickness raging from 0.1 – 8 mm (OCEANWISE#4 2012), heavy industries such as wind turbine have much higher limits of thickness needed to be weld together such as 40 – 120 mm. This has proven to be one of the barriers to use this technology, but, due to recent advancements in optic technology the focal focus of higher powered laser beams has increased, thus rending possible the welding of thick steel plates (OCEANWISE#4 2012). According to scientific magazine, “with the use of laser technology it would be possible to penetrate the entire plate thickness of more than 40 mm with a single run” (OCEANWISE#4 2012), something that would result in great time and cost reduction as currently the man hours needed to weld such thick plates is twice as much.

Last but not least, there is great concern regarding the noise that is produced during the installation phase of piles. As described earlier, the piles installed in each of the legs of the jacket by being hammered into position, something that creates harmful noises for marine mammals. Both in jacket and monopile, measures have to be taken in order to isolate those noises and which can be rather expensive.

Tripod and tripile foundations

Figure 5 4: Tripile foundtion

Source: (Engineer 2012)

The foundations presented here although they are considered two different structures, they both represent an alternative approach of an already existing structure which is the monopile. Both of them use three legs, in contrast to the monopile which uses only one, to widen their footprint in the seabed (Smadjia 2013).

Their main difference is that although they both use three pile legs to secure them in place, the tripod consists of one central column which extends below sea level, where it is welded with the three legs-sleeves, through which 40 meter long piles are driven into the seabed. On the other hand, the tripile foundation must be thought of as three distinct piles also hammered into position, which extend above sea level on top of which a transition part is used so that it can connect the three together and finally support the wind turbine (Smadjia 2013). Each of the piles can have a diameter around 3 meters (LORC 2011).

Figure **5.4** represents a tripod which although uses a wider area compared to a monopile and is considered more stable for deeper waters, it cannot compete with jacket foundation which is also used in the same depths. The reason lies in the big diameter of the bracings and central column resulting in “a large surface area prone to wave loads” (LORC 2011). They are also more massive than jackets with weights that can reach up to 700 tones and they are not widely used in wind turbine industry (Smadjia 2013) (LORC 2011). Tripile on the other hand, is considered a great improvement next to a monopile and is far more used than the tripod. In relevance to tripod foundations, they offer a smaller surface on which water can apply force onto as the diameter of the legs is much smaller than those of a tripod and the connection between them and the transition piece takes place above sea level (LORC 2011).

Investment

At this sea depth, there is a tendency amongst the structures appearing and was earlier described. They all (jacket, tripod, tripile) consist of steel which has to be welded in place, committing many man hours and increasing the overall investment cost. Also, it has to be considered that steel is an expensive material and the more complex the structure is, or in the case of the tripod the biggest it is, the more expensive it gets. As described earlier, advancements in welding technologies could help wind energy compete with other favorable by politicians technologies, such as hydraulic fracturing, used for the extraction of gas from rock formations (OCEANWISE#4 2012).

Drawbacks

A few of the drawbacks already mentioned for the previous foundations appear in these as well. First off, the installation of the piles for the three legs may even cause permanent damage to marine mammals and as mentioned earlier taking measures against it may be costly thus, alternative solutions have to be found. To continue with, both of these foundations are quite complex because of the post pilling that has to take place, resulting to the use of large vessels which are linked unavoidably to higher expenses.

Gravity Foundations

Figure 5 5: Gravity foundation

Source: (Engineer 2012)

Gravity foundation rely on its massive weight to stay erect and finally manage to counter all the forces applied in the turbine (Smadjia 2013). Although these structures are considered to be suitable for depths of up to 10 meters, some projects have located gravity foundations in depths of up to 27-30 meters such as the Thorton bank project in Belgium (LORC 2011).

The shape of the foundation itself is rectangular while in the past was influenced by the turbine itself and as a result was round. Rectangular shapes were much easier to construct thus minimizing the cost as no preparations were required for their construction (LORC 2011). Alongside with the complexity of creating a circular concrete foundation, also “the casting of the foundation has to be done with specially built formwork”, thus making the procedure more complex (LORC 2011).

The preparation needed for the construction of gravity foundation surpasses every other foundation type. First of all, with the use of gravel and concrete, the seabed gets a leveled surface on top of which the whole structure is going to be built. The next step of the installation is the placement of the support structure which can weigh as high as 6500 tones (LORC 2011) and other than being transferred on site by huge vessels, it can also be floated on site. After its’ installation, the placement of the ballast takes place which will stabilize the whole structure by increasing the weight of the structure. The weight of the ballast can reach 3000 tons or even more, resulting to a structure 45-80 meters high (LORC 2011). The ballast my consist of sand, concrete or rock (Athanasia Arapogianni et. al., [Wind in our Sails, EWEA] 2011). It has to be mentioned that the supporting structure is made also from concrete.

Investment

As mentioned in monopile section, for depths between 20-30 meters, pre-fabricated concrete structures can be way more cost efficient than monopiles and jackets due to the use of concrete instead of steel. Comparing to monopile structures, gravity foundation can cost "four to five times lower than steel monopiles and ten to fifteen times lower than jacket structures" (Ballast Nedam 2004). As a result, concrete solutions can prove to be cheaper than monopile foundations which are widely used due to their "lower cost" in popular belief of the industry (Ballast Nedam 2004).

In addition, some savings can be realized during the installation of this foundation type due to the fact that support structure sometimes is being floated on site, minimizing the use of large and expensive vessels.

Drawbacks

One of the first drawbacks that is linked to this foundation is the same as monopile foundation, called "scouring". Due to its immense weight, gravity foundations have to be insured against the relocation of seabed, which will result in an unstable structure due to the inconsistency of the base (Dixen 2012). On the other hand, gravity foundation avoids any kind of noise generating acts that can be harmful to marine mammals simply because it has no need of pile installation. Finally, the gravity concrete structure has a really long life time, reaching 100 years, and as a result it can be moved to a new site, where a new wind turbine can be installed and further pursue cost effective ways of wind produced electricity or aim for complete recycling of the foundation iteslf (Gording J. n.d.) (LORC 2011).

Chapter 6: Site selection

As this paper tries to analyze potential areas of offshore wind energy development in Greece, the fact that the areas chosen from MEECC are freed from any other use narrows the scope of all the available space in Greek waters. Specifically, there are twelve different areas that they were assessed according to data selected, which indicated the wind speed potential, the available access to the main grid, how deep or shallow water is and finally the size of the area which is available for offshore wind turbine development.

All of the above criteria had a simple grading system and all had the same weight factor as none was considered as more important than the others in this initial assessment. The grading system fluctuated from -1 to +1 with -1 given to an unfitting parameter, 0 given for a common not worth looked at parameter and +1 for a highly praised parameter and they were all accumulated to result in a final number assessing the overall potentiality of the site under the above four mentioned criteria. All of them had the same weight factor as none had a different grading scale, thus, affecting the final result by the same percentage.

As explained earlier, the areas selected by MEECC were going to be dedicated to offshore wind development. Reason being, that the rest of Greek waters are being utilized for other purposes, it is fair to say that the site selection for this paper would come out of those twelve areas. An example of how those areas are graded is given in the following table.

Offshore wind park	Proposed area spread (acreage km^2)	Wind speed	Grid connectivity	Water depth	Available area for development	Final grade
Ah Straths	5	+1	-1	0	-1	-1
Alexandroupolhs	55	0,-1	+1	+1	+1	+2
Kimis	9	+1	+1	0	-1	+1

Table 6 1: Grading of the potential areas of development by MEECC

This initial grading was done to give a first glimpse of how those areas stand according to the specified criteria. As seen in table **6.1**, the area of Ah Straths has a final score of -1 meaning that it will not comprise a priority for investment at least not for big projects. By looking closely it becomes clear that although wind speed at that location is high, or at least enough for wind energy production, the grid connectivity scores -1 which probably means that the initial investment for any project to connect to the main inland grid will be high and there are probably no available grid installations to support major projects. Water depth scores 0 which equates to water depths that may exceed 50 meters, in any case having scored zero it also means the opposite, that there is, even if it is small, some potentiality in the area where water depth is below 50 meters. Finally, the first area scores -1 to the last criteria which indicates that there isn't enough space for big projects something that is also indicated by the 5 km^2 dedicated for offshore wind development.

The second area called Alexandroupolhs has two scores for wind speed which in the end are taken accumulatively, these scores are 0 and -1 which imply that the area has rather low average wind speeds. For the rest of the criteria the area scores the highest possible score translating to available or easy grid connectivity without large capital investments, water depths of less than 50 meters and large available area for project development something also shown by the 55 km^2 proposed area spread for the indicated offshore wind development area. This second area is analyzed here to show another reality, an area which scores a final grade of +2, one of the highest between the twelve areas, has rather low wind potentiality as implied by the studies of MEECC. In order to compensate for this low average wind speed, the area indicated for development is the largest between the twelve and accompanied by grid availability and proper water depth it could translate as a proper area for the creation of a big project with much taller turbines in order to make up for the low average wind speed.

Finally, the third area of Kimis, which is the area selected for further analysis in this paper, scores the highest in average wind speed and grid availability +1 accordingly, water depth at the area is graded with 0 meaning the same as in the first area of Ah Straths, that there might be some available areas of proper water depth in the proposed by MEECC area spread. Lastly, the available area for development is graded with -1 as it is rather small, as in the first example of Ah Straths, with only 9 km^2 of dedicated area for offshore wind development. The final accumulative score for area of Kimis is +1, but, this final result is not representative of the challenges that any investment company would face in the realization of any project in the area. The analysis in the following chapters, will try and assess mainly the economic and environmental aspects or barriers which are present in area of Kimis.

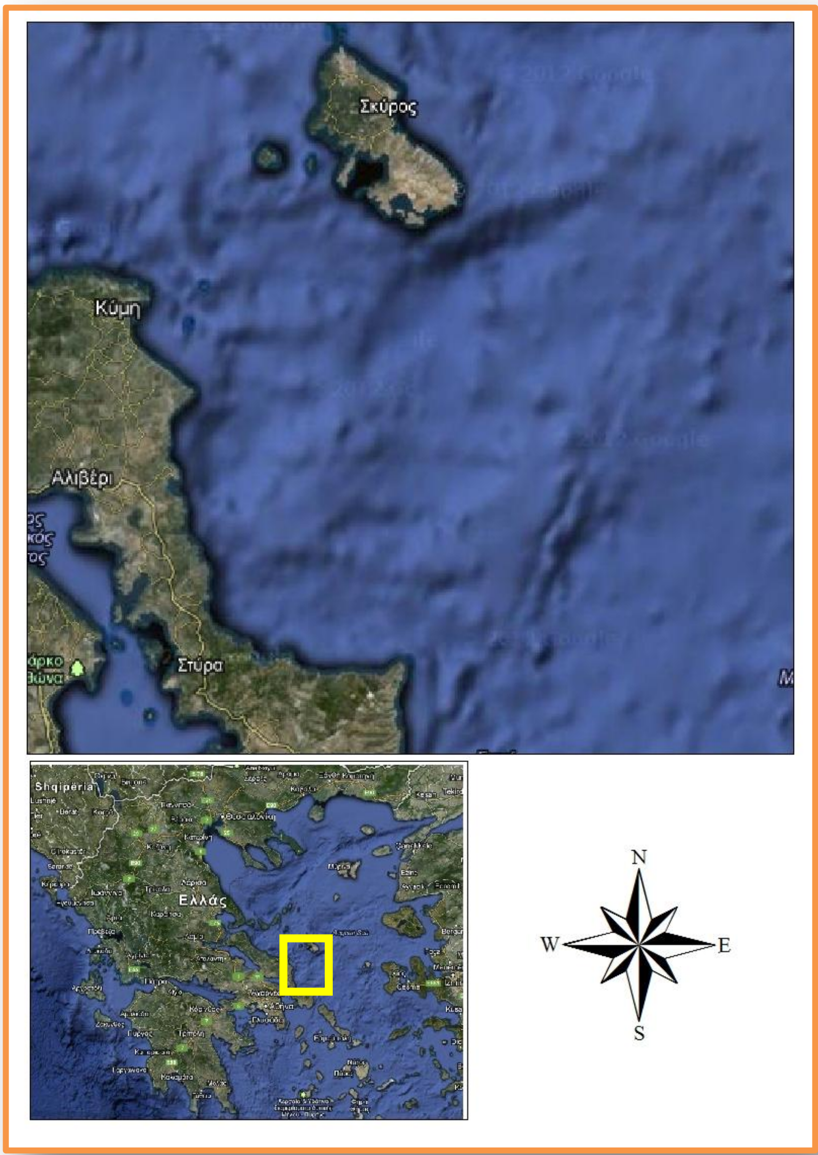

Figure 6 1: Site selection

Source:

To begin with, the above figure illustrates the area of Kimis. The smaller map is Greece, where with a yellow rectangle the area of Kimis is illustrated relatively to Greece. The rest of the figure is comprised by the map of the area zoomed in. Although all the studies of the area stopped at a very early stage, MEECC had proceeded in spatially placing an offshore wind park as it will be shown in the following figure. The criteria used other than having the area free of any other uses and having water depth less than 50 meters, were to be outside of protected areas, outside firing range areas for military purposes (f. p. MEECC 2010). Additionally, although this first sitting was done irrelevant of the average wind speed in the area, it was to be used as a measure of evaluation (f. p. MEECC 2010).

For this first stage and according to MEECC, the wind turbines were placed in distance of 8DX8D which for turbines of 5 MW capacity and diameter of 126 meters, this equates 1000 meters space in between each turbine (f. p. MEECC 2010).

Figure 6 2: Offshore wind park of Kimis area

Source: (f. p. MEECC 2010)

Figure **6.2** indicates this first sitting of offshore wind park in the area of Kimis which is the area of choice for further analysis in this paper. The bigger rectangle which is placed Southern from where the offshore wind park is being sited is a military firing range. This sitting did not comprise a final selection for the area as no environmental studies were taken into account. MEECC did not make clear how many wind turbines were to be placed in the area indicated above. The sitting of the wind park in figure **6.2** above, was done by MEECC and another thing that they did not make clear is what criteria they used for this sitting, if any.

Chapter 7: Site analysis

By taking into consideration the first selection of areas for the development of offshore wind parks as indicated in Chapter 6, the analysis of this chapter will focus in indicating the study area through the use of ArcGis software. As it would have been done by MEECC, the analysis will follow a few steps to include several criteria each of which will play its role in selecting the final polygon where the offshore wind park is going to be placed. Through the use of ArcGis software, the creation of maps is possible and as such, each step can be indicated appropriately.

Furthermore, this chapter tries to justify the initial selection of this region of Greece dedicated to the development of offshore wind energy. For that reason, here is the initial grading performed by MEECC only mentioned briefly, as it was more thoroughly discussed in chapter **6**.

- Proposed area spread (acreage km^2): 9 km^2
- Wind speed +1
- Grid connectivity +1
- Water depth 0
- Available area for development -1

Chapter 7.1.1: GIS presentation of the site selected

The first step will be to indicate the depth of water in the area selected. It is worth mentioning that a depth of <50 meters was chosen, as the appropriate water depth. The technology of floating offshore wind parks is still in an experimental stage, as already mentioned, thus the proper water depth is defined by the available foundations. As it was mentioned in the technology review chapter, jacket foundations have been used for less than 50 meters water depth, with monopile foundation being the prevalent choice for water depth less than 30 meters. Gravity foundation has been used mostly for water depths of less than 10 meters, but, in some cases they have been used on 20 and 30 meters as well (LORC 2011). Each of the foundations represent an investment cost and that is the reason why it is important to further analyze the water depth.

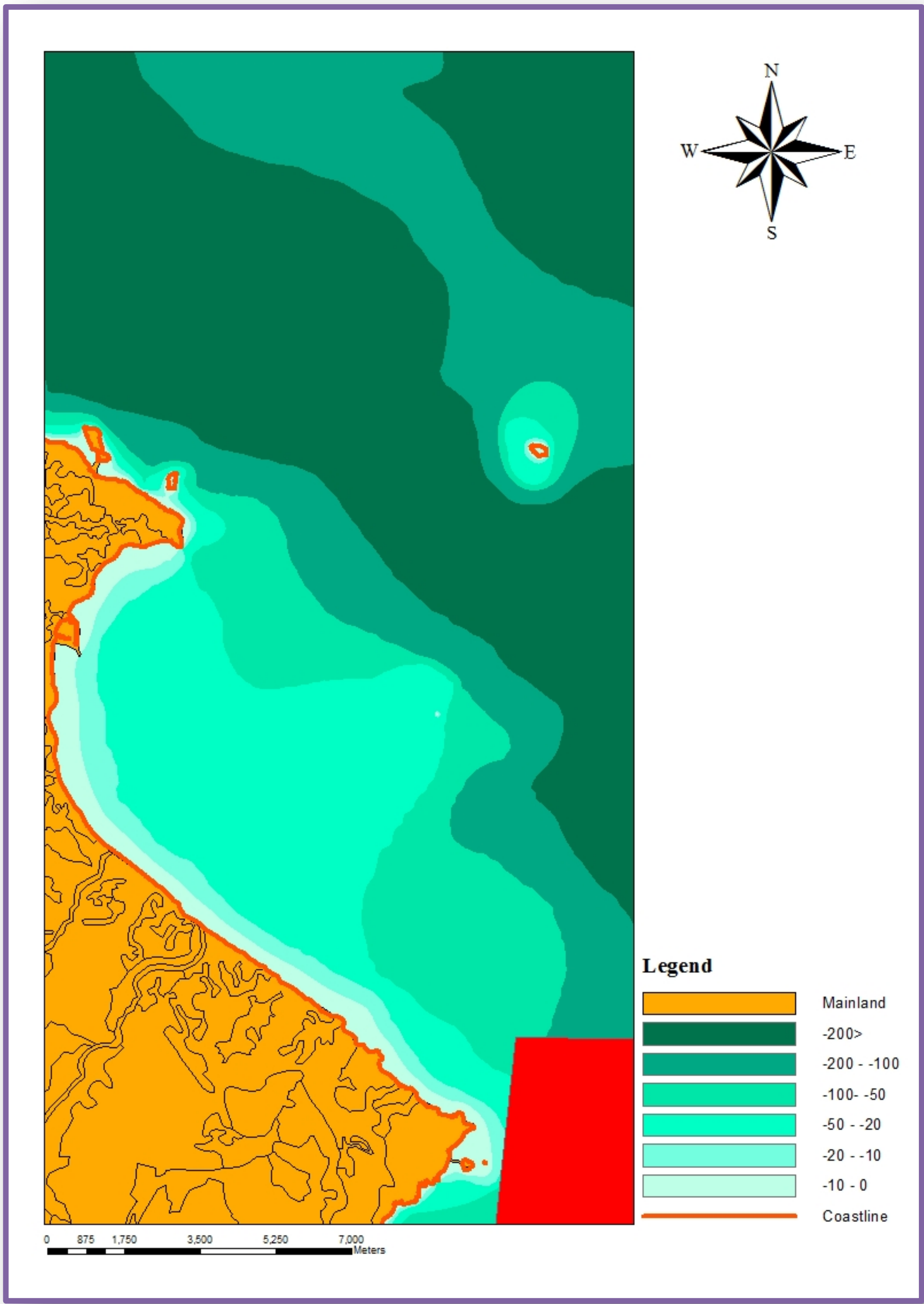

Figure 7 1: Bathymetry of the area of Kimis

The above map shows the bathymetry of the area of interest. As indicated by the legend of the map **7.1**, the bathymetry consists of different shades of blue. Starting with a very light blue-ish color, the bathymetry there indicates water depths of less than 10 meters and the deeper it goes the darker this color gets eventually reaching depths that exceed 200 meters in less than 9 km from the shore and according to measurements on ArcGis software. To the South Eastern side of the map, a red rectangle is placed which indicates the area which is used by the Greek army as firing range. This area has already a dedicated land use and thus, is excluded from the sitting selection. Another aspect that is worth highlighting is towards the North Western part of the map, where a small inhabitable island is located. Although the water around that island gets shallower and creates a natural submerged valley, it does not reach appropriate meters for the current foundation technologies. Otherwise, that region could be considered as a good candidate.

Another reason why figure **7.1** is being presented here, is to indicate how one of the specific aspects taken into consideration from Greek government can be illustrated. The figure that follows displays more aspects of the area as it is shown by the legend of the map. Instead of presenting and illustrating each one separately, gathering all of them gives a better understanding of the area of interest which is further analyzed.

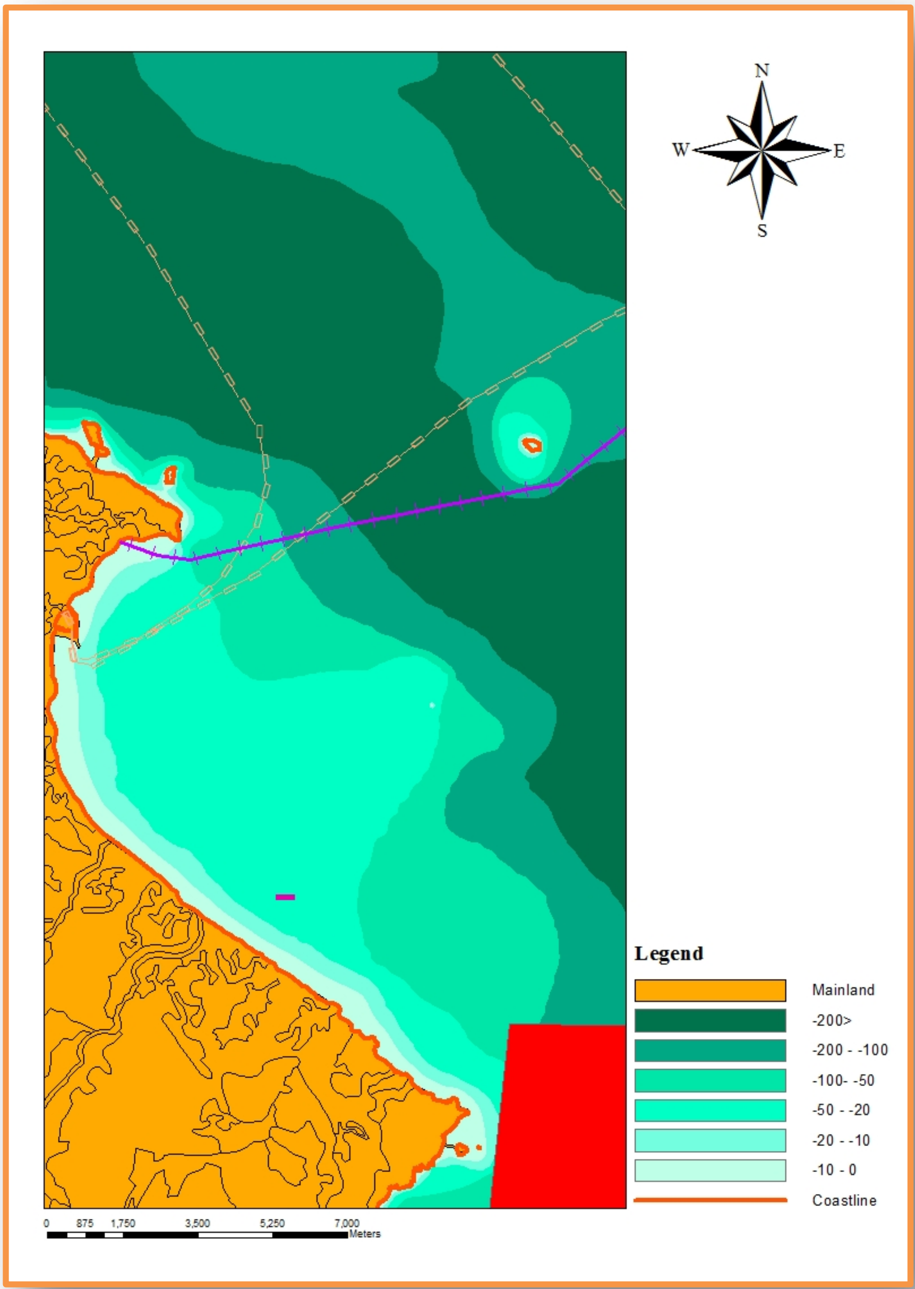

Figure 7 2: Characteristics of area of Kimis

The data presented in figure **7.2** partly justify the selection of the area for wind development. As it is shown, the area is relatively free of any other uses and thus a wind park can be freely sited in that regard. As the initial grading of the region indicated, the area is grade with +1 for having spatially easy grid connectivity, something that can be seen in figure **7.2** as well, where the purple line indicates a submerged high voltage cable leaving the mainland, heading towards the Greek islands. Because there is a submerged cable in the area, there is also going to be a transformer so that it can transform the voltage of the current produced by the wind park for the needs of the network.

Additionally, the light orange color in figure **7.2** represent ship lines performed regularly from commercial ferries heading to many nearby islands. The tourist harbor of the area can be considered either neutral or advantageous for the wind park. As it is not a harbor used by industries or container ships, it is not certain that it can be used during the construction of any project in the area, as the sheer size of the large vessels used for these purposes might be a prohibiting reason. But, the fact that small boats can sail from that harbor for inspection reasons during the lifetime of the project, can be considered advantageous.

Last but not least, a small magenta line towards the South Eastern part of the harbor can be detected. It represents the location of a ship wreck, which has been found and characterized by the archaeological authorities as important. Regarding the validity of such data, considering the fact that the map, which was original digitized in ArcGis software, is created by the navy and it is being updated frequently, it is fair to say that they are highly precise.

With a first glimpse, the available area of offshore wind development is sure to be placed inside the natural gulf created East of Kimis, which is characterized by water depth less than 50 meters and from a big underwater valley of stable depth of <50 meters (light green color). Adding to that argument is the facts that, in the Northern part of the map close to the coastline, the waters are getting deep in a faster rate as depths of more than 100 meters are met in less than 1 km from shore and that the Southern part of the map is dominated by the existence of the firing range polygon which extends even Southern than what is possible to be depicted in this map.

Chapter 7.1.2: Highlighting the area of development through the use of buffer zones

The analysis of the area is also based on the sitting criteria as indicated by Greek government (Greek Goverment Newspaper 2008). The criteria were part of the initial spatial planning of sustainable development for RETs, part of which was the reformation of licensing procedure which was analyzed earlier. These criteria have been stagnant throughout the years that followed and until today they remain unchangeable as no projects have taken place.

	Outside border of Natura region or any other monument of nature (km)	Community of more than 2000 habitats (km)	Tourist area or a region that has a tourist harbor (km)	High voltage cable	Lighthouses (not indicated, min. safe distance)	Archaeological zone (not indicated as part of the world heritage list)	Commercial ship line routes (not indicated, min. safe distance)
Minimum distance	0.2	1	1	1.5d (rotor diameter)	1.5d (rotor diameter)	0.5 km	1.5d (rotor diameter)

Table 7 1: Minimum distance buffer zones

Source: (Greek Goverment Newspaper 2008)

These criteria are the ones that directly affect the area of study as it will be indicated in the following part of this chapter. The study undertaken by Greek government went on and specified several other factors that do not relate with the area of interest, thus, they were not included in the above table e.g. minimum distance from a traditional settlement. Regarding the minimum distances kept from lighthouses and commercial ship line routes, it was defined the same as the minimum distance set from high voltage cable and it was done as it was not defined in the first place.

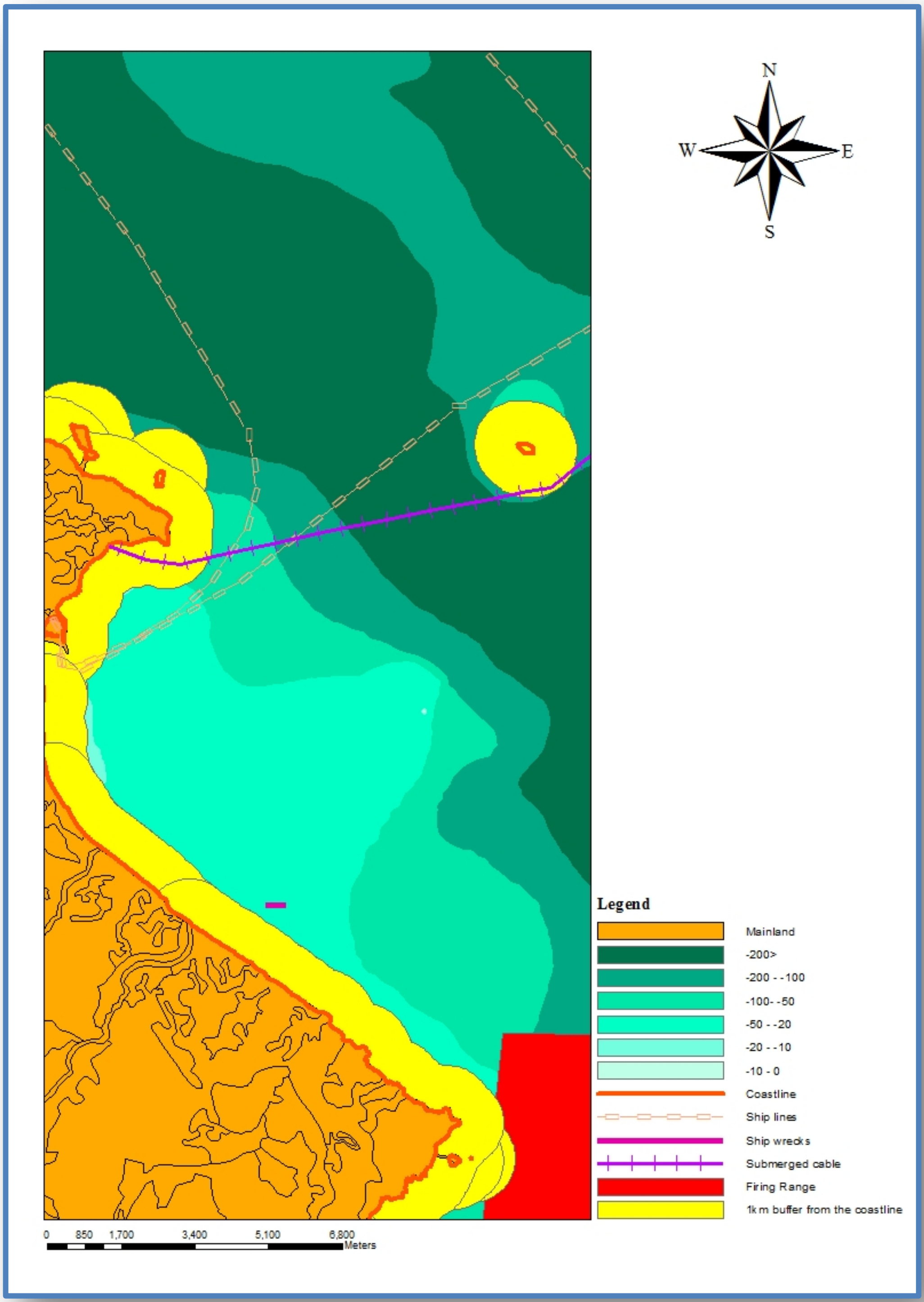

Figure 7 3: 1km minimum buffer zone from shore

Figure 7.3 is created to illustrate one of the buffers created according to the criteria set in table **7.1** above and give an example of how a buffer will look like in the final map that will follow. As it was defined, the minimum distance that should be kept from shore, which in our case has a community of more than 2000 habitats and also a tourist harbor, is 1 km. Thus, the yellow outline shown in the figure above, is a zone created from shore inside which no wind turbines are to be placed according to this criteria. One thing to be mentioned here though is that along with that zone of exclusion, water depths of 0 – 20 meters are excluded as well. A very small part of the light blue line indicative of 20 meters depth and below, can be seen to the central Eastern part of the mainland.

The creation of this first buffer has a rather important outcome as it indicates that the available area for wind turbine development is characterized from depths of more than 30 meters. As chapter 5 of this paper mentions, the foundation which is more suitable for such depths is jacket foundation as monopile foundation is rather unstable considering the hydraulic pressures created at this depths. Also, similar projects have used jacket foundation as it was mentioned briefly in chapter 5, for depths of up to 45 meters.

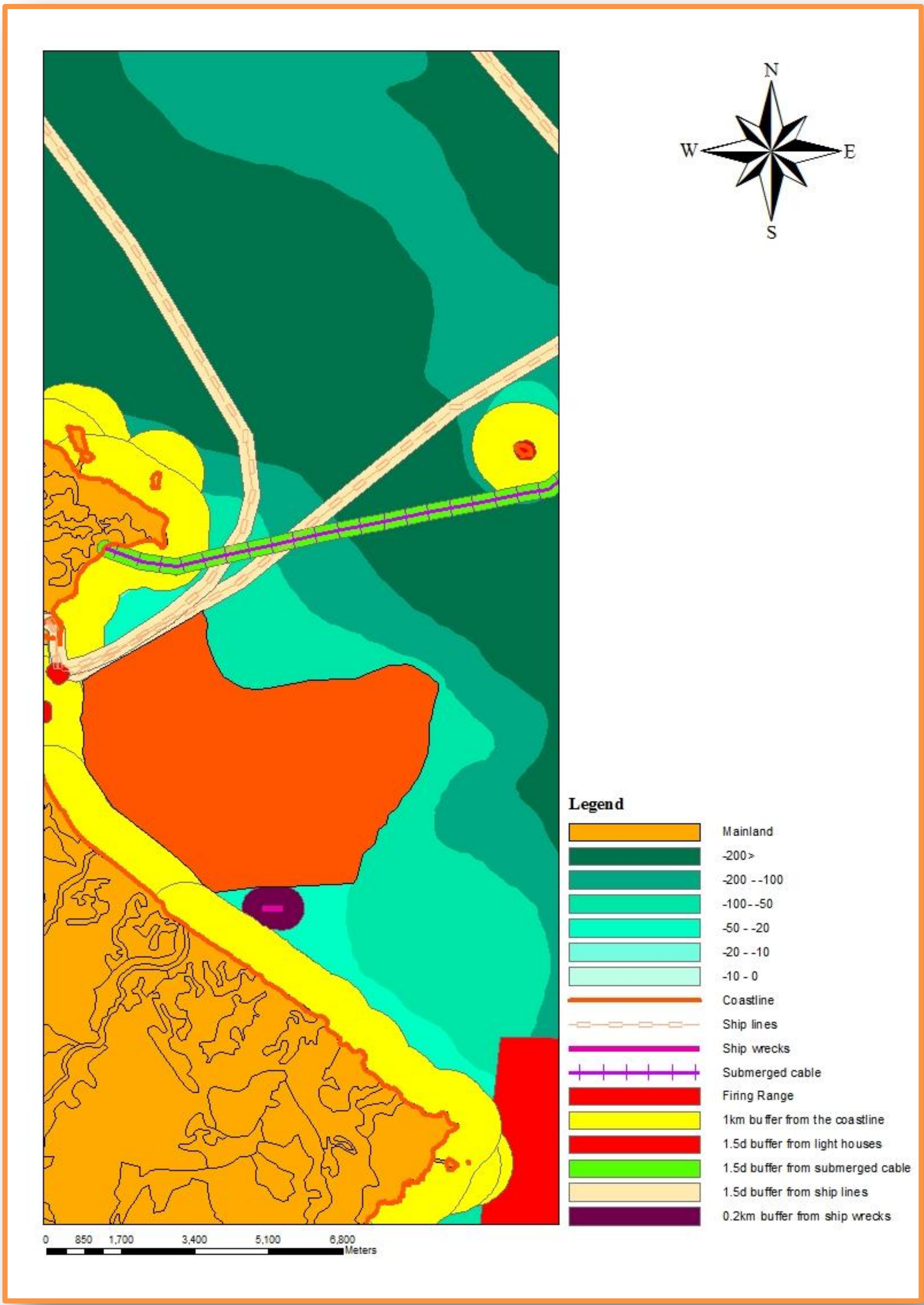

Figure 7 4: Presentation of minimum buffer zones

As it was implied earlier, the above map includes all of the buffers created according to the criteria presented in table **7.1**. Specifically, the lines that were presenting commercial ship lines and the submerged cable are bulkier as they now utilize more area and more specifically 1.5d. (d=rotor diameter). In the above situation, the rotor diameter that is used is 125 meters and it is that of a 5 MW wind turbine. Additionally, there is a buffer zone created around the ship wreck which is characterized as an important area and as such a 0.2 km buffer is selected. Lastly and although surrounded by larger buffers, the map indicates the small buffers created around the light houses indicated with red color.

Regarding the orange colored area, as the legend indicates, is the area for offshore wind development. As expected, it occupies the space right at the point where the buffers finish and spreads all the way to where bathymetry changes and goes deeper than 50 meters. As a result the perimeter of the polygon takes its shape by being adjacent and by not overlapping the buffers of ship lines, submerged cable, buffer from shore and to the South the buffer from ship wrecks. Regarding the Southern part that of the ship wreck, the polygon draws straight above it, in order to keep the polygon as uniformly shaped as possible.

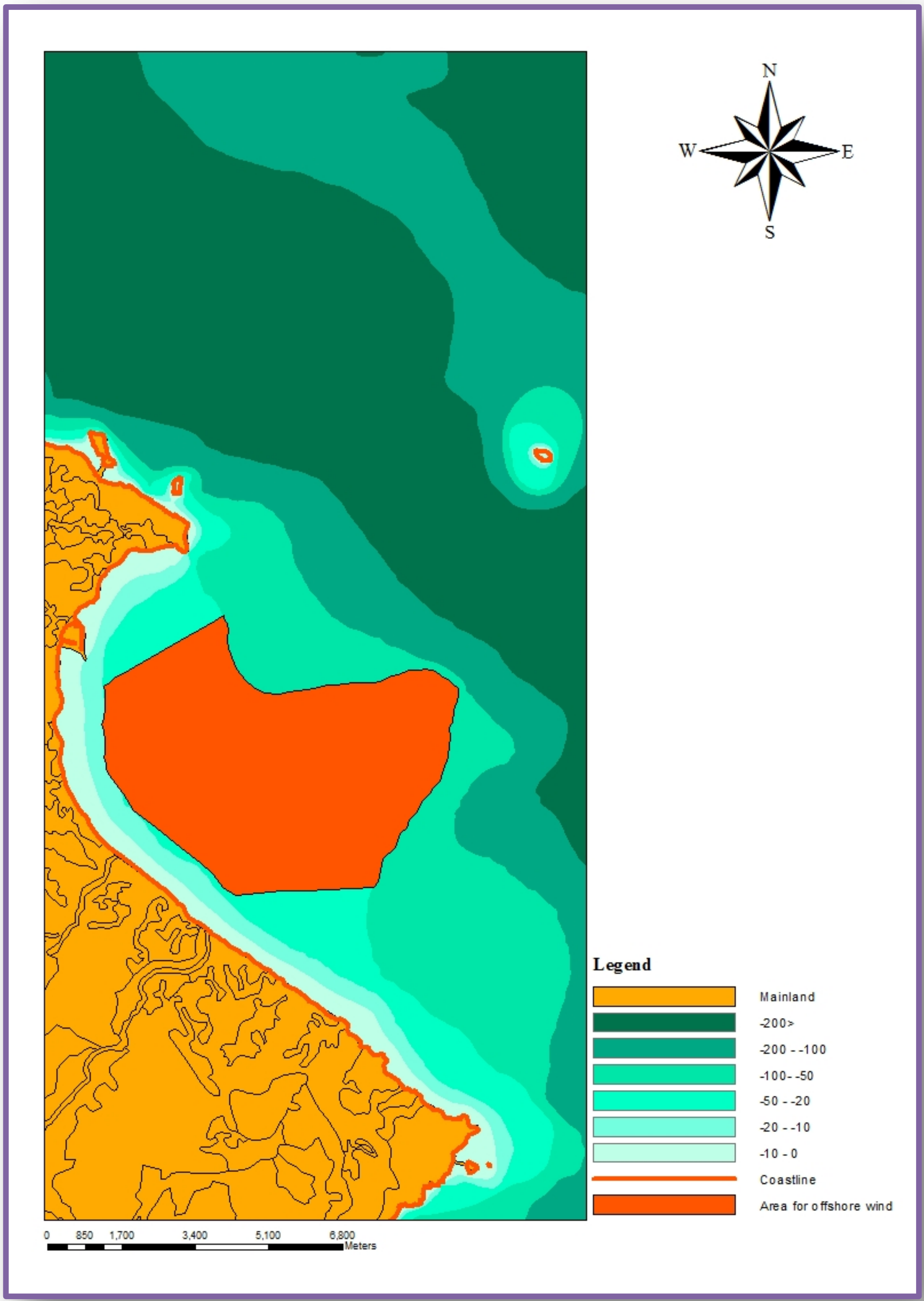

Figure 7 5: Are of offshore wind development

The result of the site analysis indicates the polygon with orange in the above figure. It covers an area of 38 km^2 inside which any potential offshore wind projects are going to be located.

Chapter 8: Future possible results, economic analysis of a potential wind project

As it would happen in any offshore wind project, the relevancy of any wind park to the initial investment and the economic parameters surrounding it, would play a major deciding factor in any decision taken from this point on. Keeping in mind that the mentioned in Chapter 7 area would be offered to the highest bidder, the investment company would go into further analyzing the available factors and aspects and as such, the paper will draw upon bibliography review and some of the facts highlighted in the GIS analysis to further conduct an economic analysis in order to unravel the barriers surrounding the area and as a result the feasibility of any such project.

Investment costs for offshore wind parks cannot be established as easily as onshore parks, the possible combinations which derive from local and spatial characteristics create a big range of outcomes which as a result make the end investment costs of each site sensitive toward different factors (EEA 2009).

	Turbine	Foundation	Installation	Grid connectivity
Share of total investment costs for offshore projects (%)	30-50	15-25	0-30	15-30

Table 8 1: Percentage of the participation of the components of a turbine to the investment

Source: (EEA 2009)

Table **8.1** presents four different components of any offshore wind project and the range at which they fluctuate while being part of an initial investment. The actual percentage at which each of these aspects participate in the final project, which will be different for each project, affects the sensitivity to that specific aspect. The fluctuations of the aspects listed above are attributed to different reasons as it is indicated in the following paragraphs.

Regarding the turbine itself, its' cost is depended on its capacity as this factor affects the sheer size of the turbine. Larger rotor diameter can achieve higher power outputs, as a result the bigger the turbine and its parts, the more material need for its creation. Although fluctuating, steel, is one component used and defines the final cost.

Installation can also affect investment costs as shown in table **8.1**. As it was briefly mentioned in the technology review chapter **5**, the use of big expensive vessels for the installation of foundations and wind turbines is costly. That cost is interlinked to the time needed for each turbine to be installed including travelling on and off site. As it is expected the more these huge vessels are used, the more the initial investment has to be stretched. It is worth mentioning that downtime due to weather adds extra economic burdens to any offshore wind project, as it adds to the overall time needed for the completion of the installation (EEA 2009).

Another cost that is directly affected by the distance of the offshore wind park to the shore, is the cost of grid connectivity. For parks that are closer than 50 or even 60 km to the shore, AC (Alternating Current) can be used and it is a common approach used for the majority of wind parks. Furthermore, the use of AC facilitates the distribution of the electricity generated from offshore wind parks to the grid as it is characterized by the ease at which its voltage can change to the levels required, through the use of transformer stations. Additionally, the use of higher voltage throughout the transmission of electricity, minimizes the loses of the system (Athanasia Arapogianni et. al., [Wind in our Sails, EWEA] 2011). As a result, this method of electricity transmission is most likely to be used to the site of Kimis which is located so close to shore. The other option would be changing AC to DC in order to be transmitted to longer distances without having considerable loses but as it turns out from many pilot projects to the Northern seas for smaller projects close to the shore something like that will not be necessary. Last but not least, the cost of the export cable connecting the wind park to the shore can be affected by many things such as "cable size sea bed conditions and the possible need for transformers" (EEA 2009).

		Distance to coast (km)					
		0-10	10-20	20-30	30-40	40-50	50-100
Cost (EUR/kW)	**Turbine**	772	772	772	772	772	772
	Foundation	352	352	352	352	352	352
	Installation	456	476	488	500	511	607
	Grid connection	133	159	185	211	236	314
	Others	79	81	82	84	85	87
	Total cost (EUR/kW)	1800	1839	1878	1918	1956	2131

Table 8 2: How distance affect the cost of a turbine

Source: (EEA 2009)

The above table shows which of the aspects discussed earlier are functions of distance from shore. As indicated, installation costs and grid connection rise accordingly as the distance of the park gets longer and in through the total cost, it is shown their impact in the formation of the final capital needed for an offshore wind park per kW installed.

Cost (EUR/kW)	Water depth (m)			
	10-20	20-30	30-40	40-50
Turbine	772	772	772	772
Foundation	352	456	652	900
Installation	465	465	605	605
Grid connection	133	133	133	133
Others	79	85	92	105
Total cost (EUR/kW)	1800	1920	2227	2514

Table 8 3: How depth affects the cost of a turbine

Source: (EEA 2009)

As expected, the components of the turbine that remained without any changes to their cost as a function to the distance from shore they now get affected by water depth as it is shown in table **8.3**. It is clear from the previous chapters that for different depths, different kinds of foundations must be used and as such they have an effect on the initial cost. Installation costs also differ, as for different foundations the preparation of seabed and the whole procedure in general gets more complicated, thus large installation vessels tend to be used more and consequently adding to the initial cost.

Depth (m)	Distance to coast (km)					
	0-10	10-20	20-30	30-40	40-50	50-100
10-20	1000	1022	1043	1065	1086	1183
20-30	1067	1090	1113	1136	1159	1262
30-40	1237	1264	1290	1317	1344	1464
40-50	1396	1427	1457	1487	1517	1653

Table 8 4: Distance and depth relation to the final cost

Source: (EEA 2009)

Finally, table **8.4** presents all of the components that constitute an offshore wind park, body of the turbine, foundations, installation costs, grid connection and show which are affected by water depth and which are affected by distance to shore. As it became clear through the analysis of chapter **7**, the site of Kimis is located below 10 km from shore and in depths that exceed 20 meters and reach even

50 meters. As shown with the red cells of the table above, a potential investment in the area, according to European Environment Agency, could fluctuate between 1067-1396 EUR/kW.

Chapter 8.1: Cost calculations of the hypothetical wind park project

Taking into consideration the three different prices that were indicated in Chapter **8**, of 1067 EUR/kW for 20-30 meters, 1237 EUR/kW 30-40 meters, 1396 EUR/kW 40-50 meters, this chapter will focus on examining the Net Present Value (NPV) of a hypothetical project in the area consisting of five 5MW wind turbines, a total output of 25MW and of initial investment capital of 1067000x25=26675000 Euro, considering that the area is sited in water depths between 20-30 meters. Regarding the NPV, it accumulates all the possible positive incomes or negative payments of the project over a period of time and applies a discount rate, which for our calculation is set to **12%**(**JUSTIFY)**, to the amount. The same is done for the loses which in this case are operation and maintenance of the project, which remains constant throughout the lifetime of the project and according to bibliography is set between 0.012 - 0.015 EUR/KWh produced. As these calculations are going to analyze the highest cost scenario, it uses O.M. costs of 0.015 EUR/KWh (EEA 2009). Finally it sums up all these different costs along with the initial investment, to indicate over a period of time if and at which point the project pays back its initial investment.

Regarding the potential income of the wind park, the practice that was followed until now in Greece indicates the following, the Public Power Corporation (PPC) was obliged to buy renewable energy from private investors of the Greek energy scene. As a result contracts of 10 years duration with the possibility to extent it for another decade (Oikonomou 2010). The proposed price for parks that have output bigger than 50 kW and are not interconnected to the mainland is 99.45 EUR/MWh (Oikonomou 2010).

In order to use this fid in tariff regime that was just mentioned, there is a need to calculate how much a potential wind park consisting of five 5MW wind turbines would generate throughout a year. To do so, the paper introduces at this point the definition of the capacity factor, it is the ratio of the true power produced by the wind park to the theoretical power that the wind park would produce if it was working the total hours of the year at its full power (Soren Krohn 2009). According to National Renewable Energy Laboratory (NREL 2012), the capacity factor that has been achieved throughout offshore wind parks ranges between 27%-54%. As it was indicated by the definition, the capacity factor illustrates how well a wind park performs in relation to its theoretical output, it also includes the loses of the specific project. As such, for the calculations that are going to follow, the smallest capacity factor is going to be selected (27%) as in this way the final result will indicate the risk of investment in the area of Kimis. If by selecting a rather high discount rate and a low capacity factor the hypothetical project has a payback period lower than its lifetime and additionally has a profit, the risk of investing in the area is low, considering that much higher capacity factor can be achieved and the discount rate can be lower.

$$\frac{x}{8760(hours\ of\ the\ year) * 25MW(wind\ park\ output)} = 27\%$$

The above equation gives as a solution the potential electricity that would be generated by the described hypothetical project and is equal to: x=59292 MWh. Now that the production of the wind park is produced, it is also assumed that it remains constant throughout the years and as a result the O.M. (0.015EUR/KWh) can also be calculated and they also stay constant throughout the years and get discounted through NPV:

*O.M.=59292MWh(produced annually)*15EUR/MWh=889380 EUR*

Last but not least, the net produced income which is used for the calculations derives from:

*59292MWh(produced annually)*99.45EUR/MWh=5896589 EUR*

Taking into consideration all of the above next step is the actual calculation of NPV given from the following equation:

$$NPV = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

R_t= net value produced in year *t*
T = Years (0,1,...,N)
N = Project period (20 years)
i = Discount rate (12%)

The following figure shows the result of the NPV calculation for a period of 20 years which is the minimum lifetime given for an offshore wind turbine. Usually it ranges between 20-25 years (Soren Krohn 2009). As the hypothetical project follows an extreme scenario, the lowest life span for the whole wind park is selected, 20 years.

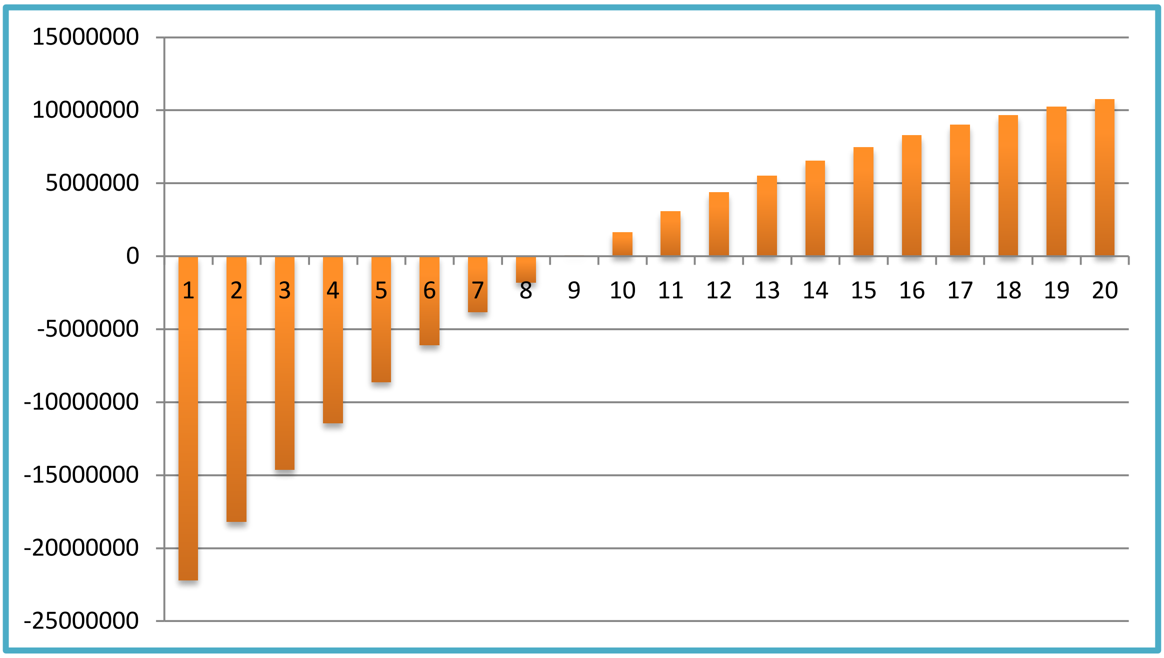

Figure 8 1: NPV calculations

The table above is the accumulative NPV calculation of both the incomes and the costs throughout the years. More specifically, the following equation was used:

$$NPV_{total}=NPV_{net\ income} - NPV_{O.M} - \text{Initial investment}$$

As it is presented in figure **8.1**, the project realizes profit in its ninth year of operation, what this also means is that in that year the project pays back the initial investment which was 26675000 EUR for five 5MW wind turbines installed. What is also worth mentioning is that as already mentioned, the PPC (Public Production Company) is more or less obliged to offer contracts of 10 year duration which automatically means that in that period the project will be profitable, although marginally. As the potential of renewing that contract exists, a new decade of profit can be added for any investment company (Oikonomou 2010), which makes the area of Kimis a good candidate. The final accumulative profit made throughout the whole life time of the project is 10726068 EUR.

Chapter 8.2: Scope of the hypothetical wind project

So far, the analysis of this paper has followed in the footsteps of what was set as target by the Greek government. To continue with, this chapter tries to indicate the potential value toward the Greek government, of this specific analysis. As it would be done in a real case scenario, it is highly probable that great resistance would be met by the local municipality, in case such project would tried to be implemented and especially in this specific area of Kimis which has a commercial harbor and the whole area is characterized by heavy tourist traffic. Thus, this chapter tries to indicate how the analysis of this paper can be used for negotiation reasoning with the local municipalities, through the use of environmental valuation. But first of a definition of what is environmental valuation is needed.

To start the argument of valuing environmental benefits, if those are valued depends strictly on the preferences of each individual. According to (John O 'Neil 2008), Utilitarian approach is the maximization of a welfare of an individual through meeting his/her preferences. But because there are many preferences that one can value and some might even be intangible, there is going to be a separation based on (John O 'Neil 2008).

- Use values represent the satisfaction that the individual gets by the use of a good
- Non-Use Values are divided into three categories. Firstly, the option values that refer to the preferences for a good that might be used or not, an example might be the aesthetic value of a pure view that the sea offers to the local municipality by just being there. Secondly, bequest values are those that show preference for presenting a good for others including future generations an example is the preservation of the local biodiversity for future generations. Thirdly, existence values are preferences for goods that maybe will not used by anyone, an example might be set as the existence of an endangered species in the vicinity even though an individual might never run into it.

By following the Utilitarian approach for each individual the biodiversity of the sea or the clear view towards the sea have different meaning according to his/her values. There are recreational preferences like diving or fishing in the area of interest, or aesthetic preferences like having beautiful surroundings, or intrinsic values like the calming effect that the clear view of the sea might have on them or the happiness that they might acquire by doing so.

In conclusion, the behavior of people is what creates the preferences and values and for the purpose of addressing these values and preferences in order to achieve a better well-being, environmental preferences should be valued.

Theoretically, environmental valuation is being used in many cases in order to asses all the different values surrounding an environmental benefit. This approach, is usually being conducted by economists who want to value specific aspects of the environment in order to include it to their economic calculations. Also, it sets a benchmark by which all of them (aspects, environmental benefits) can be compared and measured. According to (John O 'Neil 2008), this benchmark is the monetary value and consequently this part will analyze the different approaches that can be employed to assess the benefits.

To begin with, the replacement cost technique takes into account the cost of replacing or restoring a damaged asset and afterwards uses this cost to value the restoration benefit. When considering this method for an offshore wind park, an example can be given in the following way, one has to assume that there is some damage done to native fauna or flora, the money that an investment company would have to spend in order to restore the local biodiversity in its previous state represent the value of the benefit of restoring this area. As a result, the environmental benefit of having a fully functioning ecosystem might be valued by this value.

The opportunity cost approach makes no effort on assessing the environmental benefits but instead, it values the benefits of the activity that might be causing the environmental degradation and sets this cost as a way of showing what should be the minimum cost of the environmental benefit so that it renders the development of this activity worthless. For example, a possible valuation of the view or the aesthetic of the scenery around the area of Kimis should be valued in a minimum amount of a five 5MW wind turbine park.

Hedonic pricing is an approach in which a proxy good in the market is being used as a measure to estimate the value of the environmental benefit. A valid example for this approach is, the difference in price for a hotel room in a tourist area facing a wind park and another one that is free of any such visual disturbances.

Finally, Contigent valuation is the method by which the evaluation of a specific benefit is done through asking individuals how much are they willing to pay for it, or how much do they accept as a compensation for its loss. This is the method that is going to be further analyzed in this chapter as the question of what is someone willing to pay in order to move the wind turbines by some distance, will be the base of the negotiations presented later on. This method will be linked to the resistance of the local municipality towards the sitting of the wind park in area of Kimis and will be used as an alternative to try and mitigate the final result of resistance and unwillingness to accept the project, mainly due to visual disturbance.

Chapter 8.3: PIZ (Public Investment Zones)

Having accepted so far that the area of Kimis is characterized by the heavy traffic of tourists or keeping in mind that any other area indicated by the Greek government for offshore wind development in the future might also fulfill such a role, it is safe to assume that the government must have a public plan in order to make any relevant project acceptable by the local municipalities and also restrict any investment plans who might be overambitious and jeopardize the environmental or aesthetic value of the area.

Without further ado, the public plan which was conceptualized for this part of the project goes by the name PIZ which stands for Public Investment Zones.

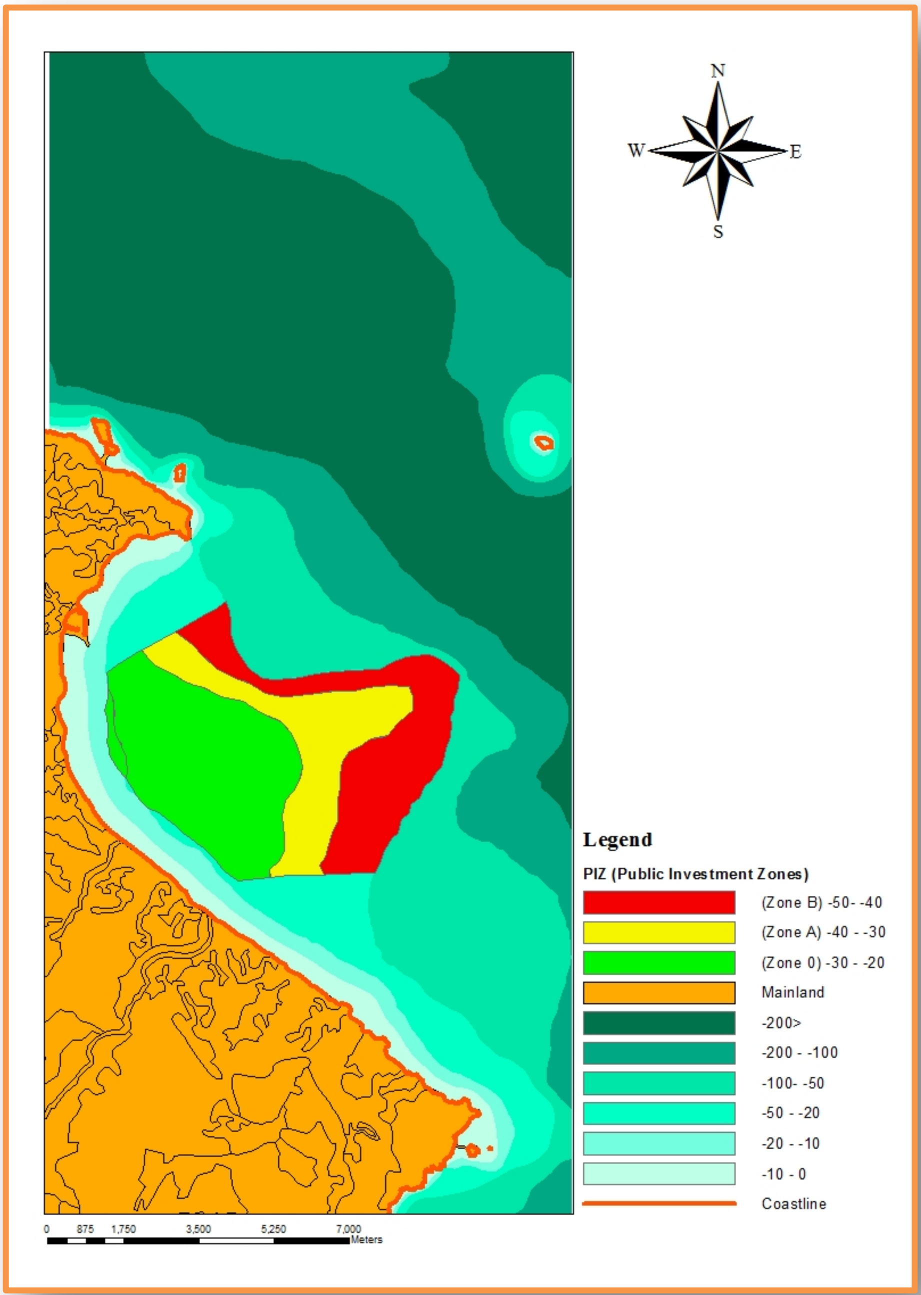

Figure 8 2: PIZ

Figure **8.2** above, illustrates how the area indicated for offshore wind development in chapter **7** is divided in three zones which are the following:

- Zone 0 characterized by water depths of -20 to -30
- Zone A characterized by water depths of -30 to -40
- Zone B characterized by water depths of -40 to -50

Chapter 8.3.1: PIZ ZONE A

First off, before explaining the reasoning behind the creation of those zones, it must be highlighted that the available bathymetric data for the digitization of the isobathic lines in GIS software, did not include those of 30 and 40 meters and in order to be constructed, the analysis was based on scattered data of bathymetry on the map in order to create those specific hypothetical isobathic lines of the region.

Continuing, as the area highlighted by the three different zones is the indicated result after the implementation of the criteria set forth by MEECC, the whole area would be theoretically available to the highest bidder. PIZ plan at this part follows a slightly different approach and indicates that the Greek government should only start the bidding process of Zone 0. In the unlikely case that there is public acceptance of the project, the hypothetical project is the following, as this zone has water depths of -20 to -30meters the cost calculations that are valid for this area were presented in chapter **8.1**, where it was also indicated that an investment company realizes profit with the parameters that were selected.

PIZ plan, comes into action once there is high public resistance and the hypothetical project is not accepted by using the contingent valuation method and asking **if** the local municipality is willing to pay and not **how much** they are willing to pay so that the wind park can be moved further back and reduce the visual disturbance. Government now takes up the role of negotiator, as without having revealed to the investment company the Zone A or B it now has room to succeed a result where both public and private good are balanced. Thinking back to chapter **8.1**, the initial investment of the wind park is affected by both water depth and distance to shore in the following way, 1067 EUR/kW for 20-30 meters, 1237 EUR/kW 30-40 meters, 1396 EUR/kW 40-50 meters for a distance less than 10 km., as such, moving the wind park to Zone A the initial investment cost changes and through PIZ that connects this amount of willingness to pay with a percentage of the initial investment of the offshore wind park there are several different outcomes:

- Includes public opinion to decision making
- Rewards the local municipality for accepting this project by making the investment company pay the equal percentage (or in different cases x%) of money spend for the initial investment, out of the annual wind park's income
- Making PIZ to cover for the difference of initial investment cost from Zone 0 to Zone A

It has to be mentioned that for the cost calculations, the same capacity factor is kept as in chapter **8.1**, which indicates that although the park is moving to a new location of deeper waters and further from shore which might mean higher average wind speeds and greater energy production, the paper assumes the same energy production aiming at the analysis of a worst case scenario. The discount rate is also kept the same as in chapter **8.1**. Also, the calculations assume that the full amount of O.M. costs are paid only by the investment company and not by the municipality. The initial investment is formed in the following way:

$$IC_{PIZ\ Zone\ A} = IC_{30\text{-}40meters} - IC_{20\text{-}30meters} = (1237000_{(EUR/MW)} * 25_{MW}) - (1067000_{(EUR/MW)} * 25_{MW}) = 4250000$$

- $IC_{PIZ\ Zone\ A}$: the initial investment cost paid for PIZ Zone A
- $IC_{30\text{-}40meters}$: the initial investment calculated for 25MW wind park for 30-40 meters with cost 1237000EUR/MW
- $IC_{20\text{-}30meters}$: the initial investment calculated for 25MW wind park for 20-30 meters with cost 1067000EUR/MW

The income which is directed toward the municipality will be a percentage of the income realized each year. This percentage is the following:

$$\frac{IC_{PIZ\ Zone\ A}}{IC_{30-40meters}} = 13\%$$

As indicated by the equation above, the municipality will pay 13% of the initial investment so that It can be moved to PIZ Zone A and as a result it will be getting a 13% annual income of the annual overall profit of the park. It is worth mentioning that the profit of the local municipality is also discounted over the years as the percentage is taken out of the discounted annual amount and it goes through the NPV calculations as well. Regarding the NPV of the project, it is given from the following equation:

$$NPV_{total} = NPV_{net\ income} - NPV_{O.M} - NPV_{PIZ\ Income} - IC_{20\text{-}30meters}$$

It is important to highlight at this point, that as seen in the equation above the Investment Cost taken into account for the calculations of the NPV_{total}, is the investment cost of the project if it was located in Zone 0 as the difference is paid by PIZ Zone A.

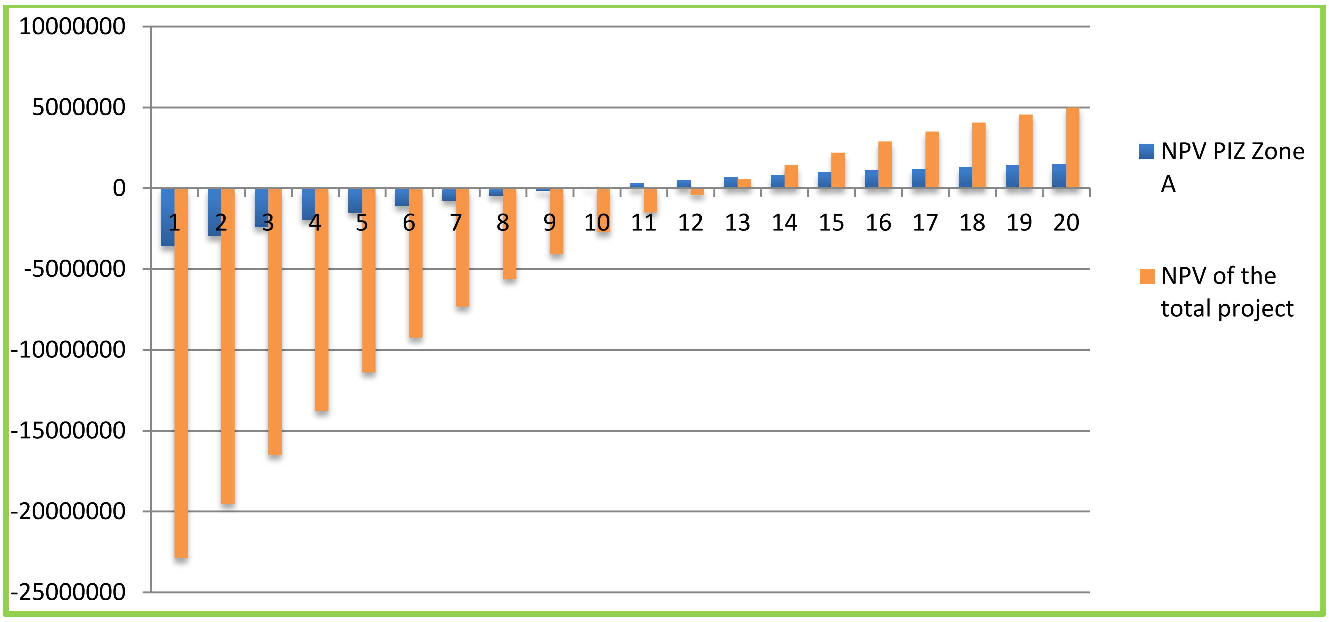

Figure 8 3: NPV of project including NPV of PIZ Zone A

As indicated in the figure above, both investments of the company and the PIZ for Zone A are paying back after a certain period. In detail the initial investment of the total project is being paid back in its 13th year of operation when it also has its' first year of positive accumulative profit. In comparison to NPV calculations of figure **8.1** which was done for the hypothetical project located in PIZ Zone 0 and it paid back the initial investment in its 9th year, the same 25MW project in PIZ Zone A pays back the initial investment 4 years later. Something like that was expected, as at the same time some profit has to be made for the PIZ which as seen above has a payback time of only 9 years. Both the investing company and local municipality have an accumulative profit in the overall lifetime of the project, 5000317EUR for the company, 1475751EUR for the local municipality.

Chapter 8.3.2: PIZ Zone B

By following the same calculations performed for PIZ Zone A, this part analyses another outcome. In case the local municipality and in general the public opinion is not willing to accept the construction of the hypothetical project in PIZ Zone A either, the last option of the PIZ plan is to move it further away in Zone B. As it was indicated in figure **8.1**, this Zone has water depths that range from -40 to -50 and as a result the initial investment is expected to rise again. As it was done for PIZ Zone A, the local municipality will be asked to pay for the difference of the initial investment, when moving the park from Zone 0 to Zone B.

$$IC_{PIZ\ Zone\ B} = IC_{40\text{-}50meters} - IC_{20\text{-}30meters} = (1396000_{(EUR/MW)} * 25_{MW}) - (1067000_{(EUR/MW)} * 25_{MW}) = 8225000$$

- $IC_{PIZ\ Zone\ B}$: the initial investment cost paid for PIZ Zone B
- $IC40\text{-}50_{meters}$: the initial investment calculated for 25MW wind park for 40-50 meters with cost 1396000EUR/MW
- $IC_{20\text{-}30meters}$: the initial investment calculated for 25MW wind park for 20-30 meters with cost 1067000EUR/MW

The income which is directed toward the municipality will be a percentage of the income realized each year. This percentage is the following:

$$\frac{IC_{PIZ\ Zone\ B}}{IC_{40-50meters}} = 24\%$$

Once again as it was indicated in PIZ Zone A, the local municipality pays 24% of the overall initial investment cost in order for the park to be moved in PIZ Zone B. Accordingly, the local municipality realizes an annual profit of 24% of the annual overall income of the park. In this sense, although the investing company is not burdened for the move in deeper waters with higher construction costs, it does not gain the whole annual profit. The profit of the PIZ Zone B is discounted over the years, as it is calculated after the calculations of the NPV of the annual profit. Regarding the total NPV of the project it is given from the following equation as it was done for PIZ Zone A:

$$NPV_{total}=NPV_{net\ income} - NPV_{O.M} - NPV_{PIZ\ Zone\ B\ Income} - IC_{20\text{-}30meters}$$

As seen above, the initial investment cost taken into account for the hypothetical project is the one if it was placed in PIZ Zone 0 and the difference is paid by PIZ plan.

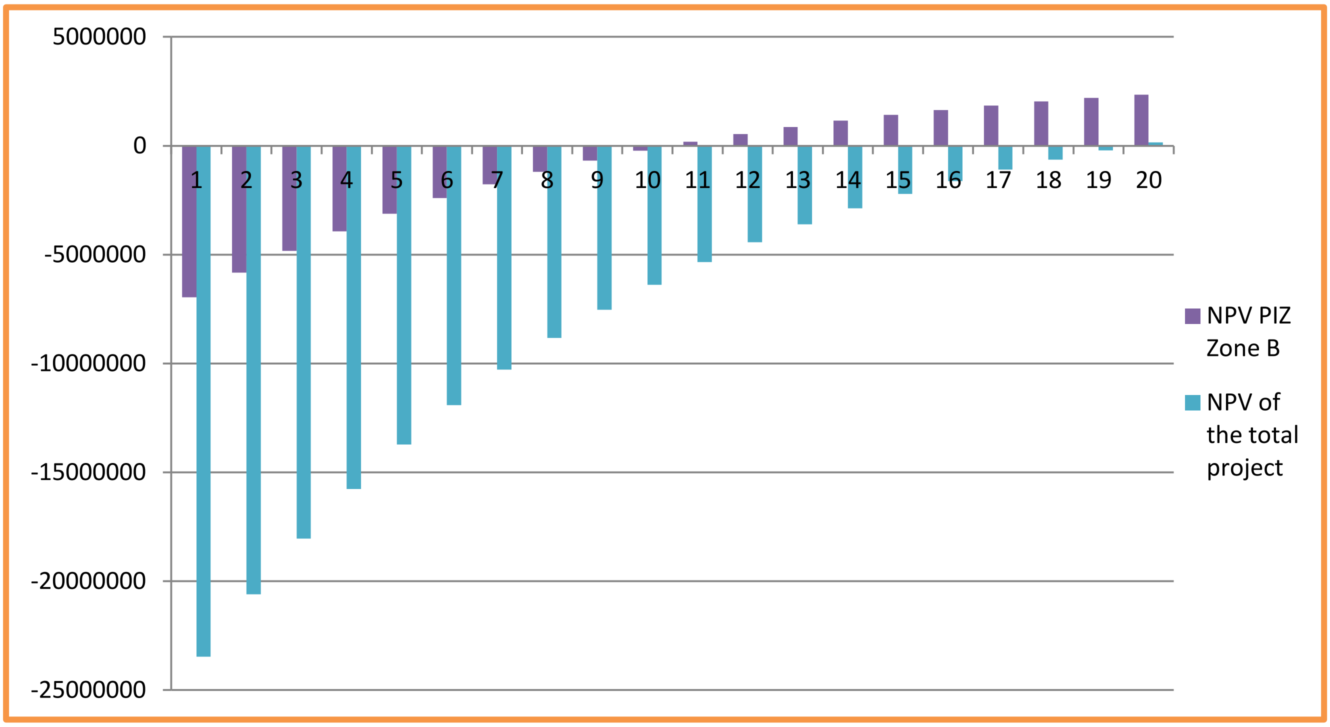

Figure 8 4: PIZ Zone B

The results presented in Figure **8.4** are quite different in comparison to figure **8.3** of PIZ Zone A. As the capacity factor of the park is unchangeable throughout the three Zones, it is assumed that the annual production of the park remains stable as well. Keeping that in mind, the annual income of the project remains also steady throughout the three Zones but with one difference, a bigger portion of it is being redirected towards the initial investment cost of the PIZ plan. As PIZ Zone B has an initial contribution of 24% to the overall investment cost of the project, the same 24% is taken out of the annual profits making it marginally possible for the total investment cost of the project to be paid back, which it does in the 20th year. For an initial overall project investment of 34900000 EUR for both PIZ and investing company, the company has accumulative profit in the 20th year rising to 155450 EUR, much lower than 5000317 when it was located in PIZ Zone A. Regarding the investment cost of PIZ Zone B, it is paid back much earlier than the one of the investing company, in the 11th year of operation of the park, the PIZ has the first year of accumulative profit and in the 20th year this profit rises to 2345618 EUR. In comparison to PIZ Zone A, Zone B, has higher initial investment of 6961445, 11 years pay back instead of 10 and has higher profit than that of Zone A.

After having presented the Zones of PIZ plan it is important to highlight some facts that render the procedure itself possible. First of all, the actual presence of Greek government in the overall procedure of PIZ is of the highest importance, as without it this outcome would not be possible. Thinking back to Zone 0, the investing company has no actual reason to deny the construction of its project there, as it fulfills all of the criteria presented in chapter **7**, it is only when Greek government comes into action that makes PIZ plan possible.

By concealing the fact that the actual area of development is larger than just Zone 0, the PIZ plan assures two possible outcomes, the first is that the investing company has no other option but to accept the location proposed and local municipality to either accept the project or deny it through NIMBY lobbying. If NIMBY lobbying takes action so does PIZ plan by providing the options discussed earlier, PIZ Zone A becomes available for development only in case the local municipality is willing to pay part of the initial investment so that the park can be moved. Also, Greek government makes this transition possible by making the investing company to give part of its earnings to the local municipality, in order to realize profit and finally come into terms with the actual materialization of the project.

As seen through the creation of the two Zones, the balance itself is rather sensitive to investment cost changes. In one hand, it is really important for the PIZ to have profit throughout the lifetime of the project, as in this way the local municipality will not consider the offshore wind park a lost cause and a loss of money. In the other hand, it is really important for the investing company to have profit in the end of the project. The Greek government itself, has to make the whole project as attractive as possible for both of these entities, so that it can succeed in implementing it.

As it was shown from figures above, the profit realized for the investment company in each of the Zones dropped significantly, especially in Zone B where water depth is between 40 and 50 meters. While trying to make the public accept such a project, it is important to also create initiatives for the investment company so that to make it profitable for the company to invest. This is where policy design comes into play, there are several different approaches to that extend. A simple change in the FIT scheme would be enough for the whole investment to seem attractive in the eyes of the investor.

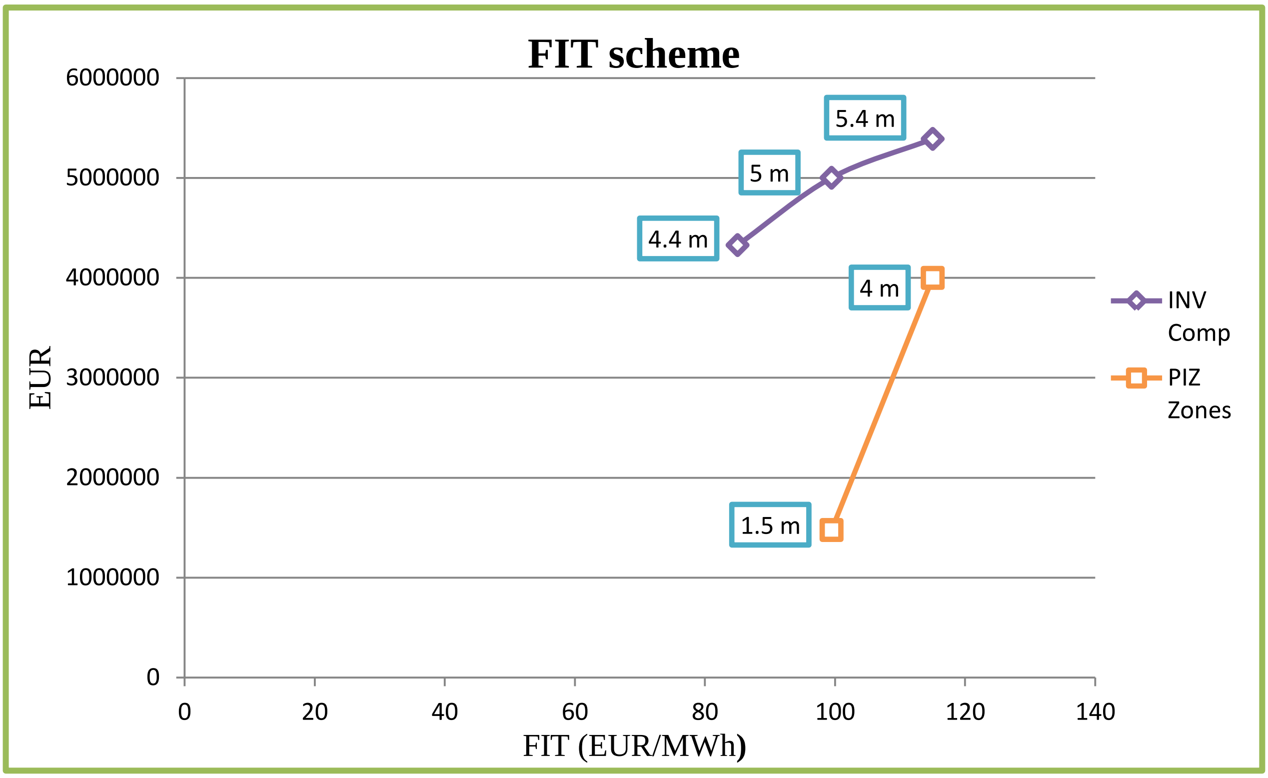

Figure 8 5: FIT Scheme

Figure **8.5**, shows how the overall accumulated profit of the project changes when the FIT is changing as well. The prices that were used for the creation of that figure follow the thinking of having the investment company making profit throughout the PIZ Zones in order to keep the investors interested in the area. The exact prices that were used are the following, for the first Zone 0 instead of using the fixed FIT of 99.45 EUR/MWh a lower price of 85 EUR/MWh is selected as this Zone is characterized by the shallower waters and as a result the costs per MW installed is rather low, the profit at this case is 4.4m EUR for the company. Also, a lower price is selected in order to be able to redirect the investors to another Zone by offering the already existing FIT of 99.45 EUR/MWh. With that in mind, in case the second Zone A is selected for the sitting of the project, the FIT that is offered is high enough for the profit of the investing company to be higher than it was in Zone 0, thus, making it more attractive with total accumulative profit of 5m. For the last Zone B which poses the higher challenge as well, the highest FIT was selected in order to maintain the interest from both private and public sector. For 115 EUR/MWh, the final accumulated profit of 5.4m is again higher than the previous Zones, although marginally, and manages to be a viable solution.

Regarding the increase of FIT itself, thinking back to the year 2006 when the old prices of FIT regarding PVs (Photovoltaic) came into power after the then legislation was voted, prices were as high as 171 EUR/MWh for bigger than 100 KW plants (PV Magazine 2013). Although this first energy scheme of Greek government could be considered as a good first step in order to make the public interested on the matter, the outcome was extreme as a lot of farmers and land owners went straight to the creation of PVs farms, leading to the achievement of the capacity targets set from Greek government rather early and drastically cutting down FITs. As a result, careful thought has to be put into the FIT scheme creation for offshore wind energy and in that regard it seems rather logical to have an ever so slight increase in the already FIT when having an overall sitting plan as this, which includes policy design on the making. Summing up, FIT increase has to be used wisely and through offering marginal profit increase in the overall lifetime of any project in order to support a policy outcome, seems more relevant than abrupt increases for no apparent reasons.

Chapter 9: Conclusion

As it was also indicated in the methodology section, since the early chapters of the thesis, the analysis follows the scope of the Greek government. As early as chapter **3**, by focusing on the past this thesis tries to present the main reasoning behind the actions taken in regard to offshore wind development. By presenting the driving force behind those actions, which were the targets set through the 20-20-20 directive, it tries to justify how Greece was planning to tackle the challenge of addressing those targets. The year 2009 was a milestone for the newly formed Ministry of Energy and Climate Change, which was burdened with that challenge. Ambitious plans of the licensing phase reformation and the so called "planned capacities" of wind energy suggested high activity in the offshore Greek energy scene.

As such, chapter **3** present the following years and criticizes the outcome of the claims in chapter **2**. As it became immediately understood, MEECC was convinced of the efficiency and role of offshore wind in achieving their targets. As it was done in that period, chapter **3** analyses the first step of MEECC, the reformation of licensing procedure. By presenting what was done up until 2010, it shows the slow moving decision making Greek government not having taken any initiatives and unwillingly delaying any investments to come to fruition. The rest of the chapter is dedicated to the reformation under the newly formed MEECC. After its presentation, a few of the reasons why this reformation did not work are listed. The reformation process itself was time consuming and it got to a point when due to the economic recession and future uncertainties, the procedure came to a halt.

From that point on, the thesis fulfills the role of MEECC and starts the analysis from where MEECC had left off, analyzing the case study area of Kimis, one of the candidate areas indicated by MEECC for further analysis regarding offshore wind development. Based on bibliography, the initial criteria which were going to be used at that point by Greek government are being highlighted and the analysis itself begins in GIS software. After the incorporation of those initial criteria and taking into account the technical barriers of wind turbine foundations, a specific area within the case study area is being mapped where the sitting of the potential offshore wind park could take place.

Continuing onto chapter **8**, the analysis goes further and places a hypothetical offshore wind park in the area consisting of five 5 MW wind turbines. By showcasing how the distance and depth are linked to the cost formation, a specific initial cost per MW is drawn which is then used for the initial cost calculations. Knowing the bathymetry of the area, it is easy to point which of the foundation technology is of use. Regarding the production of the park, as no wind speed data were available for the exact region, the energy output is based on the equation of capacity factor and more specifically, by assuming that the hypothetical wind park sited at the area would be working with a specific capacity factor of 27%, it was then easy to calculate a potential output of energy per year that could be produced by such a park. Although the use of data for the initial cost calculations could be improved, it is not what is important in chapter **8**, which goes on to assume that the local municipality of city of Kimis would lobby against such project based in the fact that the tourist traffic in the area is very high.

Through the use of different methods of valuation, the concept of monetary valuation is being introduced at that point. Once again, the thesis tries to suggest a probable solution to that problem by using contingent valuation method. By filling the role of MEECC, the thesis introduces the idea of PIZ plan which makes use of the area of study by dividing it in three different zones. By establishing the base cost at which the offshore wind park is being constructed for Zone 0, it sets a benchmark for later on to relate to.

At this point, it is assumed that local municipality wants the park to be moved to another location, thus, PIZ plan comes into action which provides the option of moving the wind park to Zone A. To do so, as the park is moved to Zone A which is characterized by deeper water, it assumes that local municipality contributes to the overall investment in order to alleviate the investing company which is burdened with higher initial investment cost due to deeper waters. Last but not least, the last resort of PIZ plan is Zone B. In that regard, the local municipality is again unwilling to accept the project and once again PIZ plan provides with a last frontier option, to move the park the farthest possible from the shore to PIZ Zone B. The investment cost for both local municipality and investing company rises.

What this method presents is a potential balance between private and public sector. Although the presence of government is of extremely high importance in order for this plan to be successful, the outcome can be the sitting of offshore wind turbines into locations where otherwise would be rather difficult due to public resistance. In the final part of chapter **8**, the discussion takes a different course as it focuses on the implementation of a different FIT scheme so that it can change the end accumulative profit of the investment company. As it is stated, it is as important for the investment company to make profit as for PIZ, because otherwise there is no actual need for the investment in the first place.

Criticism of the paper at hand

There are a few things that could be done in order to improve the analysis of this project. Due to the limited time provided for this thesis and the availability of data, the analysis did not focus as much in the environmental characteristics of the area. Regarding the fauna, if available, some migration routes of animals such as birds or cartographic movement of marine mammals or any other aquatic life form could create new barriers inside the offshore wind development area. Regarding the flora of the region, although to some extend the analysis of this thesis tried to find wether the area had any spread of seaweed on the seabed as to be avoided from the sitting, it did not went into further analyzing the actual facts of this analysis and some more limitations might be able to be drawn from that procedure.

The analysis could go further into the actual placing of the wind turbine and through the use of WindPro software or any other relevant to it, it could include the actual calculations on the wind park such as, sitting, annual output, losses created through wake effect and study the available options. Also, detailed wind data of the area could prove really important to that extend as this paper could have used the creation of a real life scenario in further improving the actual cost analysis. As the capacity factor equation theoretically include the reasons that a wind park is performing the way it does, such as low wind speed deriving from bad sitting or loses due to wake effect which result in low actual output to what it could theoretically have produced, it does nothing to show those facts in detail and it just assumes an overall performance of the park.

Last but not least, although the costs used for the cost calculations that was given in MW/EUR might be considered highly optimistic, the fact that those produce positive incomes does not matter as much as the actual presentation of the PIZ plan and the outcomes that it could have. It is more important to understand those outcomes, as in a real life scenario having understood how a specific policy works could lead to the mitigation of a negative result wether it is related to the actual profit of a project or acceptance of it.

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