A Study of the Potential for Small Wind Turbines in Greece:

Current market status, barriers to growth and support policy options

MSc Sustainable Energy Technologies

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Summary

Wind energy today is synonymous with the extraction of energy from wind via the deployment of groups of large multi-megawatt wind turbines. Nonetheless Small wind turbines (SWT) have been also designed for the built environment in order to extract energy from the wind, while being at close proximity to buildings. Despite the fact that their technology has vastly improved over the years, SWT can be considered as still technologically immature and are rather limited in use forming a niche market in a global level which has yet to grow in competitiveness as compared to other urban-focused renewable energy technologies (RET) such as photovoltaic panels and conventional power producing methods. This Thesis focuses on investigating the potential for SWT in Greece by addressing three main research questions which regard the technological and economic potential of this technology in the country, the factors which have limited in the past and still limit their development and implementation on the built environment and support policy options which could accelerate their introduction and establishment. Due to the fact that Small Wind Turbines comprise of technological products for which little is known regarding their design options, specific technical limitations and requirements, operating conditions especially in the built environment, methods of assessing their potential annual energy yield, cost of energy parameters and investment assessing methods and are often misinterpreted as solely "miniaturized" large scale wind turbines while significant differences exist on the above factors, the necessary techno economic background are being provided for the reader to be able to understand in depth, parameters important to covering the relevant research questions. Furthermore the current Renewable Energy Market of Greece along with the SWT relevant institutions, organizations and actors, the key SWT related policy measures already undertaken by the Hellenic Government and the existing Hellenic wind potential are provided in order to depict the market framework within which this technology will struggle to be established. By the analysis conducted, the fact that the necessary legal framework and RES target related to SWT deployment have been established for years but have still to be implemented despite the fact that favourable wind potentials exist (specifically in the numerous islands and coastal/mountainous areas of Greece), is drawn.

In lack of official data regarding the current number of Business groups active on the field of SWT, installed SWT in the country as well as other crucial parameters such as total installed power capacity, a survey was conducted by means of contacting SWT suppliers and manufacturers in an attempt to quantify the level of penetration of this technology in Greece as well as identifying cost related parameters and perceive barriers by the industry. The companies willing to answer to a short questionnaire with questions which could not be covered by the information provided by their internet sites, provided valuable information which were processed and critically assessed in order to form an image of the current market status. Important conclusions were drawn based on the facts that almost all related companies are suppliers which import machines from abroad and that the majority of them have already installed a non-trivial number of SWT in Off-Grid applications, contrary to the only six On-Grid installed turbines identified to have been installed by a very limited number of companies. Other identified financial information were used in the conduction of an investment analysis through economic evaluation methods previously described (Simple Payback, Generation Cost, Cost of Energy, Levelized Production Cost) and also via the simulation software RETScreen 4 which presented with a clear image on the financial characteristics of three distinct investment scenarios such as the Internal Rate of Return (IRR), Net Present Value (NPV) and O&M costs. The most favourable scenario, where the equity payback time was equal to 7,1 years with an IRR equal to 14,1 %, provided a basis of comparison with the predominant competing technology of photovoltaic panels in order for a comparison to take place. The conclusion depicts a marginal superiority of PV with the current market characteristics.

The barrier framework of analysis of J.P. Painuly, which divides barriers into distinct categories and adopts a top-down approach in order to gradually pinpoint the specific barrier elements which do not allow for the adoption of a Renewable Energy Technology, is employed. Based on the proposed categories and by incorporating and adapting the findings of international literature for the Hellenic case, investigating articles published in relevant Hellenic journals, sites and magazines based on their chronological order and by relying on the help provided by SWT specialists from the Hellenic Wind Energy Association (HWEA) and the Centre for Renewable Energy Sources and Saving (CRES), the Hellenic specific barriers are providing with valuable information Technical, analysed in depth, on Institutional/Legal, Economic/Financial, Market Failure/Imperfections, Market Distortions and Societal/Behavioural aspects as well as a new perspective on the main reasons the SWT market penetration has not still occurred in Greece. Also the information provided by Hellenic small wind turbine suppliers are taken into account in the identification of barriers. The striking fact that the Hellenic Government failed to follow through the issued by law regulations that would boost this market for a number of reasons, ranging from sluggish permit procedures to the overall destabilized RES funding mechanism and lack of nationally adopted Standards, is drawn and considered to be the predominant barrier.

The final part of the Thesis initially assesses existing action plans as issued by EU and US organizations and proposes a set of recommendations, policy measures and actions based on three distinct axes of analysis in an attempt to cover the inefficiencies of previous roadmaps. The recommendations target specifically the Hellenic barriers and focus in being applicable and practical. As such the introduction of the Net Metering System with specific added propositions is encouraged in order to jump start this stagnant market and serve as the "foundation" for the penetration of the technology in Greece and overcoming of the predominant barrier. Other actions include the adoption or establishment of implementation Standards, granting of Economic incentives, promotion of Social Corporate Responsibility through the adoption of SWT and raising of awareness and social acceptance, with the analysis ever focusing in the establishment of not only a viable market but eventually the creation of a relevant industry. Conclusions are provided which critically assess the manner in which the separate research questions are covered as well as provide insight on the future of this technology in the crisis and post-crisis economic environment of Greece. The strong points of the Thesis prove to be the novel business related research conducted as well as the detailed and categorized analysis of the current Hellenic related barriers which has not been identified to be present in literature or concentrated in a single document. Limiting parameters regarding the research conducted, calculations and framework of analysis are provided while recommendations for future research which will focus on investigating in depth the social aspects of SWT deployment in Greece, utilizing different frameworks of analysis regarding the barriers in order to avoid inefficiencies and researching in depth the potential benefits of SWT implementation in CSR promoting application are also presented

Keywords: Small Wind Turbines, Barriers, Policy Measures, Greece

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1 Introduction

The introductory chapter to this Thesis will provide with the necessary information for the familiarization of the reader with the concept of Small Wind Turbines and their definition according to International Standards and role within the global RET environment. Furthermore it will include facts about the current situation of Greece and its RES market in order to conclude to the three Research Questions which govern the aim of this Thesis. The content of the Thesis work will also be described in the form of a reading guideline. The scientific and practical relevance, describing how this Thesis is in accordance and how it contributes to scientific literature as well as the promotion of this technology in Greece, will be adequately provided. Finally the Research Methodology which was utilized during different phases of this Thesis will also be presented. With the finalization of the Introduction the reader will be able to progress into the rest of the Thesis with a clear view of the topics to be analyzed.

1.1 Small Wind Turbine Definition and Thesis Research Questions

At the end of the 20th century, mankind was brought to a crossroad regarding its demand for energy and its conventional ways of producing it. The evidence presented by the international scientific community regarding the gradual destruction of the natural environment as a direct consequence of our means of energy harvesting, gave new insight in whether we could continue on the same path of energy production. For few these new evidences were to be discarded as unsubstantial and this led to the decision that 'business continues as usual" but for the vast majority they marked the time for a global change. The realization of past recklessness, present apathy and possible future demise led to the creation of a new multilevel ecological movement that reached its peak with the establishment of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997. By this international treaty, industrialized countries were obligated to reduce their Greenhouse Gas emissions by (among other means) the gradual replacement of fossil fuel based energy production methods by the adoption of sustainable, low-emission, environmentally friendly energy production technologies.

One of these technologies uses the age old concept of implementing machines for the harvesting of a sustainable source of energy originating from the movement of air due to atmospheric pressure differences or wind. Although historically the first machines (wind mills) to have been used since 200 B.C in Persia aimed in utilizing the wind's energy in order to draw water or grind grain, modern specialized machines focus solely to convert wind's kinetic energy to mechanical and finally to electrical energy thus producing electricity. These machines are called wind turbines and this relatively new field of energy production is called Wind Energy. Wind Energy is today synonymous with the extraction of energy from wind via the deployment of groups of large wind turbines on so-called "Wind Farms", located either in remote regions or at high altitude regions inland (Onshore) or at sea (Offshore). The generated power depending, among other factors, on the wind potential of the area in which the wind farm operates and the size of the deployed turbines can reach multi-Megawatt or even Gigawatt scales and can contribute substantially in covering a large portion of a country's energy requirements which would otherwise be covered by conventional fossil fuel based energy production means.

Wind Energy has formed a global market which involves a large number of companies which manufacture, supply, manage the operation of wind turbines and integrate their produced energy into existing electricity grids and which is closely supported by favourable governmental and institutional policies. Europe, despite its on-going sovereign debt crises, is currently the biggest market with over 109,237 MW of installed power, followed by Asia and North America with 97,810 MW and 67,576 MW of installed power accordingly. The Wind Industry is one of the most rapidly growing industries worldwide with an annual global market growth of almost 10%, providing thousands of new employment opportunities each year. According to the Global Wind Energy Council (GWEC) (Global Wind Energy Council, 2012) at the end of 2011 more than 240000 people were employed in the industry, with the number expected to reach 520000 by the year 2020 in Europe alone. In 2012 more than two hundred thousand wind turbines are operating globally, with a total nameplate capacity of 282482 MW, while a steady growth of 20% on Wind Power Capacity has been achieved (Global Wind Energy Council, 2012). Also a steady increase is being observed in the Offshore Wind Energy field, with 1292,6 MW being added in 2012 reaching the total installed capacity at 5410 MW (Appendix). Wind Energy apart from being a clean, efficient and sustainable energy producing solution, it is also highly regarded by public opinion. Polls have indicated that the vast majority of citizens have accepted Wind Energy as a viable solution to CO2 reduction and are in favour of Wind Energy. Especially in Europe, 89% of the public has a positive attitude towards Wind Energy.

Apart from the remotely located Onshore and Offshore Farms, Wind Energy includes a third technological branch which involves the use of Smaller wind turbines (SWT), which range from being scaled down models of their multi-megawatt counter parts to completely novel design creations, aiming to take advantage of wind potential in the urban, near -urban, or the built environment as well as in populated areas where the implementation of large turbines would not be possible or preferred. Small wind turbines are specially designed in order to extract energy from the wind while being located on building rooftops or on the ground next to buildings. The generated on site electricity is sold to energy providing companies at specified prices and fed to the electric power transmission network, thus providing income to the user and energy of sustainable origin to the grid while avoiding transport losses and contributing to CO2 emission reductions in urban centres. More rarely the produced energy can also be consumed or stored in order to provide energy autonomy or an auxiliary energy source. Despite the fact that their technology has vastly improved over the years through R&D projects and academic research, they can be considered as still technologically immature and are rather limited in use.

Globally, Standardization Institutions have employed a number of definitions to categorize SWT based on different characteristics such as Output power, Rotor diameter, Rotor swept area etc. Since several of these institutions are focused on providing country specific guidelines, a number of differences are identified on the ranging values of their criteria. In lack of a globally acknowledged definition thus several categories exist, as indicated by Table 1, which may create confusion to the reader since turbines exceeding the designated limits of one country may be well accepted as an SWT by another country (i.e. in Germany a turbine of 100kW is characterized as SWT while in Britain it exceeds the nominal power output of 50kW and thus is not characterized as SWT). Also sub-categories may exist in some Standardization Institution's definitions, such as the Micro-wind turbines by the British Wind Energy Association (BWEA), while in other do not exist. Nonetheless, in order to follow a single definition for clarification reasons and since the Thesis will focus in Greece which currently does not possess of a SWT National Standardization scheme, the international standard '*IEC 61400-2: Design requirements for small wind turbines*' will be adopted since it does not include country specific criteria and includes the most adequate in terms of technology

criteria definition with sub-categorization classes based on wind speed and turbulense and hense not on electromechanical parameters (International Electrotechnical Commission, 2006).

Standardization Institution	Definition of SWT		
American Wind Energy Association (AWEA)	Rated capacity ≤100 kW - <i>Residential systems</i> : 1 kW to 10 kW - <i>Commercial systems</i> : 21 kW to 100 kW		
British Wind Energy Association (BWEA)	Rated capacity ≤ 50 kW - <i>Micro-wind turbines</i> : rotor diameter less than 2,1 m (swept area less than 3,5 m2), free-standing or mounted directly to the side or top of the attached building, usually mounted 3 m to 4 m above the ridge line of the attached building or up to approximately 16 m for free-standing systems - <i>Small-wind turbines</i> : rotor diameter more than 2,1 m (swept area more than 3,5 m2), predominately free-standing can reach over 30 m in total height		
German Wind Energy Association (BWE)	Rated capacity $\leq 100 \text{ kW}$ - Residential systems: $\leq 30 \text{ kW}$		
IEC 61400-11	Hub height less than or equal to 30 m and a maximum power $\leq 150~{\rm kW}$		
IEC 61400-2	Rotor swept area smaller than 200 m2, generating at a voltage below 1kV AC or 1,5 kV DC - for turbines with a rotor swept area less than 2 m2, the tower is not considered part of the design - for turbines with a rotor swept area greater than or equal 40 m2, there shall be a manual shutdown button and shutdown procedures - standard turbine classes defined in terms of wind speed and turbulence to cover most applications and external conditions - Max Output Power ≤ 75kw		

Table 1: Definitions of small wind turbines (Kühn, 2011)

Despite the fact that a sufficient number of companies has emerged, SWTs form a niche market mainly located in Europe and the USA, which has yet to grow in competitiveness as compared to Onshore and Offshore Wind Energy, other urban focused competing renewable energy technologies (photovoltaic panels) and conventional power producing methods. Public awareness is still underdeveloped in spite of a substantial number of reports, publications and projects aiming to identify the current market status, potential techno economical and socio political barriers as well as define manners to promote this promising technological branch. More specifically the European Commission has undertaken a number of projects and studies, with the most notable being the Intelligent Energy Europe's (IEE) Wind Energy Integration in the Urban Environment (WINEUR) program aiming at assessing the viability of this technology for European Markets. Although this program was completed on 2007, its conclusion and focus was mainly regarding Northern and Central European countries such as the UK, Netherlands and France in a pre-financial crisis stricken Eurozone. This fact renders the program's conclusions somewhat insufficient for promoting this technology in the European South where existing barriers differ substantially and SWT market is almost non-existent.

From Southern EU member countries, Greece is currently on the effort to overcome its economic crisis through the adoption of a number of measures and policies, while simultaneously keeping a steady course on the adoption of Renewable Energy Technologies (RET) as directed by the European Union 2020 Renewable energy target policy. Energy policy in Greece has the potential to make a significant contribution to the country's economic recovery (International Energy Agency, 2011) and thus Greece aims to raise the share of renewable energy in gross total final consumption to 20% by 2020, which is 2% higher than its EU obligation. Apart from large investments in Onshore Wind Energy, smaller investments such as the ones regarding SWTs will play an important part in reaching this goal (Hellenic Wind Energy Association, 2012). Taking into account the over 4 meters per second wind distribution of mainland Greece as well as the highly favourable wind conditions of the over 2000 small isles and islands and mountainous inhabited areas, it can be realized that there is potential for the establishment of a SWT market which, under the right circumstances can flourish.

Today in spite of the fact that harsh austerity measures have taken a toll on smaller scale business activities, there is an increased public interest on SWT technology, local manufacturing companies, costs, prices per kilowatt-hour of produced energy, legislation and permit issues which all lead to the question on whether SWTs are a viable option and whether they could eventually provide the user with an added profit and income. Unfortunately, although efforts have been done mainly by promoting lobbies to address the above, there is still not a collective study which clearly examines the current state of this technological branch in Greece as well as the different barriers it faces. Also the slowly emerging Greek SWT providers and manufacturers are mainly (if not only) targeting on household consumers relying on the maximization of the "Euro per kWh" factor whereas new trends, as identified by the more advanced and established Dutch or UK markets, indicate that there could be substantial gain from targeting companies which would be willing to adopt a "Greener" Profile as well. As relevant studies have indicated, investing in RET technology can enable companies to advertise a higher Corporate Responsibility Role which in turn can lead to increased sales (apart from providing profits from reduced electricity bills). These investments can be considered as part of the companies Public Relations or Marketing Strategy.

In an effort to provide with a Study of the Potential for Small Wind Turbines in Greece by focusing on the description of the current market status, barriers to growth and support policy options, this Thesis will address the following three research questions:

"What is the technological and economic potential of Small Wind Turbines in Europe and more specifically in Greece?"

"Which are the factors which are limiting their development and implementation on the built environment in Greece?"

"Which (policy) measures can help to overcome these barriers to SWT technology development?"

1.2 Scientific Relevance

This Thesis will examine the different barriers faced by Small wind turbines in Greece, identify the existing policies related to this technology, assess their feasibility of implementation and suggest a number of propositions for the furthering of this market. In order to succeed in adequately addressing the above, a specific framework of analysis will be adopted, adapted for the Hellenic specific conditions and applied. Also techno economic tools and parameters will be calculated to actively provide relative information which currently are lacking in their majority of relative literature. Information from International literature regarding the technology (Abarzadeh, Kojabadi, & Chang, 2011; Allen, 2008; Beller, 2009; Bhutta, Hayat, Farooq, Ali, Jamil, & Zahid, 2012; Burton, Sharpe, Jenkins, & Bossanyi, 2001; DNV/Risø, 2002; European Wind Energy Association, 2009; Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004; Gorlov, 1998; Hau, 2006) (Howell, Qin, Edwards, & Durrani, 2010; Jamieson, 2011; Kühn, 2011; Manwell, McGowan, & Rogers, 2002; Margaris, 2010; Mertens, Wind Energy in the Built Environment, 2005; Stancovic, Campbell, & Harries, 2009) and economic parameters (Allen, 2008; American Wind Energy Association, 2010; Beach & McGuire, 2013; Environmental Defence Fund, 2011; Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004; Harris & Roach, 2007; Madlener, 2012; Morthorst, Krohn, & Awerbuch, 2009; Simic, 2013) related to Small Wind Turbines and its unique aspects of implementation and limitations was processed in order to define the operational and financial boundaries, to establish the basic knowledge required for the further assessment of SWT related barriers and to identify the related barriers themselves.

The above bibliography explicitly describes techno economic aspects of SWT on a global scale but does not focus into a specific country. Since the Thesis concerned the Hellenic SWT market segment and its related barriers, information concerning small wind turbines in Greece were required. Such up to date Hellenic market oriented information existed in very few published documents from official sources and mainly originated by the Hellenic Wind Energy Association (Hellenic Wind Energy Association, 2010; Hellenic Wind Energy Association, 2000; Hellenic Wind Energy Association, 2012) and by the Centre of Renewable Energy Sources and Saving (CRES, 2011). Even so these reports did not include specific data regarding the current business activities of these companies as well as the current status of this market, such as number of On and Off grid installed turbines over Greece, the number of total installed capacity for On-grid and Off-grid applications, the number of installed capacity over the last five years of economic crisis and other valuable information. As such the author proceeded in conducting an investigation by contacting relevant authorities and companies in the field in an attempt to actually depict the current market status as well as future projections in the most realistic manner possible. This fact is a novelty which was not identified in the scientific documentation currently existing for Greece and as such contributes in covering important literature gaps regarding the market sector Small Wind turbines in Greece.

Furthermore, a lack of relevant in depth investment related studies was identified with again any official information available from Greece originating from HWEA (Georgakopoulos T., 2011). In order to contribute in covering such a gap, the author proceeded in a number of calculations and simulations which give realistic range estimations of key investment parameters and also focus in assessing the viability of three distinct scenarios by incorporating actual inputs which correspond to the Hellenic market reality. To the best knowledge of the author it is the first scientific document to, apart from providing the previous, assess the above criteria for this technology by incorporating recent data and parameters of an economic crisis-stricken Eurozone country.

Regarding the barriers analysis conducted for this Thesis, almost no information could be found regarding the social opposition towards SWT in Greece and Hellenic environment specific technical issues and as such the findings of international literature were used to deduce conclusions regarding the expected social opposition in the country (Burningham, 2012; Heagle, Naterer, & Pope, 2011; Kaldellis, 2003; Taylor, Eastwick, Lawrence, & Wilson, 2013; Taylor, Eastwick, Wilson, & Lawrence, 2012; WAYE & OHRSTROM, 2002) and other issues (Burton, Sharpe, Jenkins, & Bossanyi, 2001; Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004; Mertens, Wind Energy in the Built Environment, 2005; Eriksson, Bernhoff, & Leijon, 2008; Smith, Forsyth, Sinclair, & Oter, 2012; Jain, Hewitt, Spossey, & Hudon, 2013; European Wind Energy Association, 2009). For the rest of the barrier categories a number of information were identified in RES related internet site portals but also official documents from a number of institutions (Directorate-General for Economic and Financial Affairs, 2013; Econews, 2012; Energypress, 2013; Euromonitor International, 2013; General Secretariat for Industry, 2012; Greek Association of RES Electricity Producers, 2013; HWEA, 2013; Hellenic Association of Photovoltaic Companies, 2011; Hellenic Wind Energy Association & Greek Association of RES Electricity Producers, 2013; Liaggou, 2013) (Lilas & Nikitakos, 2008; Lyxnaras, 2013; Ammerman, 2011; Michanikos-online, 2013; Ministry of Environment Energy and Climate Change, 2011; Miniwind ltd, 2012; Papadoyiannis, 2013; ΗΜΕΡΗΣΙΑ, 2013). Nonetheless, the direct connection between the deficit of LAGIE's funding mechanism, the almost uncontrolled deployment of photovoltaics in the period between 2005-2011 and the inability of the according Ministry to accelerate the deployment of SWT for which the licensing procedure kept them on hold was not directly or explicitly identified in existing literature. As such this Thesis helped in synthesizing the findings of different authors into formulating the predominant barrier which prohibited the establishment of SWT in Greece. With the conclusion of the Hellenic specific SWT barrier analysis, the author contributed in producing to the best of his knowledge the first document to actively utilize the particular framework and identify all of the related obstacles for the specific technology within the specific crisis-stricken country. Relative literature was unable to be identified for Greece and as such an important gap is filled.

During the realization of this Thesis an attempt was made to provide with applicable solutions which could further the penetration of SWT in Greece. The existing literature provided with roadmaps and studies concerning the deployment of SWT in EU countries (Wineur, 2007) and in the US (National Renewable Energy Laboratory, 2012), but relevant documents for Greece were not identified to exist. General information regarding the deployment of household photovoltaics (Association of Photovoltaic Energy Producers, 2013; B2Green, 2013; General Secretariat for Industry, 2012; Sunblog, 2013; Electron Solar Energy, 2011) provided with solutions which could be applied to the case of SWT as well and also promoting strategies for RES (Couture & Gagnon, 2010; Energy Efficiency and Renewable Energy (EERE), 2008; Environmental Defence Fund, 2011; Georgakopoulos T., 2011; International Energy Agency, 2011; Ministry of Environment, Energy & Climate Change, 2010) were identified in both international and Hellenic literature. This Thesis contributed in adapting the above information into a novel recommendation plan which combines the best elements of previous foreign roadmaps in terms of analysis approach specifically for Greece and simultaneously incorporates time frame-specific, level-of-approach-specific as well as country-specific criteria. The propositions include novel solutions, such as the introduction of SWT implementation in CSR promoting applications in Greece and the adoption or development of a National Standardization Code, which were not identified in any of the above documents.

To conclude, this Thesis is the first, to the best knowledge of the author, to conduct such work and include all mentioned aspects for the particular technology and country and as such contributes in covering important literature gaps regarding the implementation aspects of Small Wind turbines in Greece. Specifically this Thesis essentially apart from providing clarification over the status of this technology in the country helps in covering the lack of a realistic techno economic study with current input data for Greece, a complete study over the barriers faced by this technology in the country and an action plan specifically for Hellenic SWT implementation. Also, in the same manner, it is the first scientific document to assess the above criteria for this technology by incorporating recent data and parameters of an economic crisis-stricken Eurozone country in general.

1.3 Practical Relevance

An investigation of the current status of the niche market of SWT in Greece is to take place in order to identify companies, products and policies along with the barriers which do not allow this technology to mature. As identified by the Thesis work, the small penetration of this technology, the few scientific documents concerning the deployment of this technology, the lack of a specific action plan for the penetration of SWT and establishment of an active market, the lack of vital information regarding the number of installed turbines and their characteristics in Greece accessible to either the general public or companies in the field as well as the fact that official Hellenic organizations, such as RAE, overlook it consistently in their current reports (RAE, 2013), indicate a general lack of knowledge/ knowledge diffusion means and more specifically a lack of relative credible publications, consumer guides and technology and safety related fact sheets which affects negatively or does not promote the general public's opinion and acceptance, the cooperation between SWT supplying companies and the overall future of the technology. The sole exceptions identified during this Thesis research regarding SWT were the reports and presentations of the Hellenic Wind Energy Association (HWEA), a non-Governmental organization, which in the recent years has conducted efforts in familiarizing the public with this technology with the issuing of a Small Wind Turbine Guide and separate presentations (Hellenic Wind Energy Association, 2012; Georgakopoulos T., 2011). Nonetheless, even in HWEA's reports and documentation, all aspects of SWT deployment are not mentioned or in the least not analysed in depth in order to provide with the full picture of the current market and technology. Also few reports were available from the Centre of Renewable Energy Sources and Saving (CRES), which did not proceed to the analysis extent of the equivalent documents of HWEA (CRES, 2011). From the research it was identified that company cooperation and exchange of information was absent, since no company knew exactly how many (On-Grid) turbines have been installed until currently. Moreover, the fact that almost all companies in the field are suppliers and not manufacturers as well as the lack of R&D oriented institutions might indicate also a lack of in depth knowledge regarding construction issues or a "plug-and-play" attitude which in most cases is incorrect or not fitting for this technology and could affect the operational characteristics of the turbine and thus derail an investment. Despite the fact that a legal framework exists since 2006, the constant changes in regulations as well as the difficulty in accessing solely SWT related information due to the fact that a specific bill concerning all of their implementation aspects does not yet exist, creates confusion or in the least hinders the attempts to pinpoint the exact requirements for installing such a system.

This Thesis will attempt to provide with the necessary information in order for readers of any discipline to be able to understand sufficiently all the important facts regarding SWT technology, describe the identified country specific barriers which will help in focusing future investigations in overcoming specific Hellenic system "pathogenies" as well as help current researching parties, investors and all parties interested in the implementation of Small Wind Turbines in Greece gain knowledge over this technology and the manner in which it can fit the current Hellenic Energy sector market. Thus it will actively

contribute in covering important literature gaps as identified above. Also it will contribute in providing argumentation in order for readers to realize the reasons why this niche market has not managed to become established in the small scale RET market sector yet as. The data of this thesis will provide a basis for comparison between SWT systems and other prevailing renewable energy technologies which have already become established in Greece regarding not only the technical but also the socio economic aspects of implementation and also will provide the key legislative acts which characterize the installation of this technology.

The fact that a number of organizations, institutions, supplying companies and other actors are mentioned in this Thesis can provide a "data" base for future academic work as well as provide direct economic and technologic related information to investors who would like to go through with installing such systems in Greece or simply the general public that would like to be more in detail informed on the subject. Finally the findings of this thesis will help suggest possible policy solution, which are currently lacking, to further the implementation of SWT and ways to stimulate this particular emerging market in Greece as well as bring together different parties in order to overcome specific barriers. This is an important attempt in covering the relevant gap in Hellenic literature and legislation.

The propositions of this Thesis take into account the country specific characteristics and provide practically applicable measures, with a special focus on how SWT ties in with a greater importance of corporate social responsibility in firms' decision making and performance, which can help further the efforts of the Government, Supplying companies and consumers to promote the acceptance and adoption of this technology. The proposed action plan of this Thesis helps in covering the Hellenic roadmap gap which was identified during the research for the completion of this project and also provides a basis for future research in specific fields of SWT which could range from raising system efficiency to addressing false high noise perception.

1.4 Research Methodology

In order for this Thesis to address adequately the proposed Research Questions, apart from literature research other methods were utilized as well. As such, a survey which attempted to cover the information gap identified in Hellenic documentation regarding SWT in the country was conducted and the framework of RES barrier analysis of J.P Painuly was adapted and applied for the Greek case. Also calculations regarding the cost of energy and other RES investment parameters were performed. In this subchapter the characteristics of the first two methodologies will be presented since the techno economic parameters relevant to the simulations/calculations will be explicitly described in Chapter 2 along with all other necessary information for the assessment of SWT investments.

Due to the lack of official information regarding key SWT parameters, such as the number of On/Off-Grid turbines installed, installed power capacity, installation locations but also information regarding active Hellenic companies (apart from the contact information, product information and additional services of a number of specific companies provided by *HWEA's Catalogue for Registered Small Wind Turbine Affiliated Companies* (Hellenic Wind Energy Association, 2012)), business activities as well as the overall status of this niche market was not possible to be determined. Thus an investigation was conducted by the author, in an effort to gather and quantify such data and present a more accurate overview of the Hellenic SWT market, by the means of interviews. The interviews, which took place between August and October 2013, were conducted by telephone communication and exchange of emails with SWT Supplying company representatives or owners and included a series of questions in the form of a questionnaire as well as open questions. The number of questions was deliberately minimized to only include information impossible to be determined from each company's internet site and in order to maximize the number of received responses, since as it was determined by initial verbal communication, an increase in questions resulted in interviewees being more reluctant to reply or participate in the overall investigation. More specifically the questionnaire included the following questions:

- 1. How many years has your company been active in the field of SWT?
- 2. How many SWT has your company installed since its formation?
- 3. How many SWT has your company installed up in the last five (5) years?
- 4. In which Hellenic regions have you installed SWT?
- 5. What is the total power capacity of the turbines installed by your company?
- 6. What is the total power capacity of the turbines installed by your company in the last five (5) years?
- 7. The turbines installed by your company concern On-grid or Off-grid applications? How many turbines have you installed per each application category?
- 8. In your opinion which is the biggest obstacle to the consolidation of SWT in our country and why?
- 9. Is your company oriented strictly on household applications? If not, for which other applications have you installed SWT?
- 10. In foreign countries (i.e. The Netherlands) the use of SWT is promoted in corporate buildings within the urban fabric for the emergence of a developed Corporate Social Responsibility (CSR) role. Companies which install SWT on their buildings include such investments in their Marketing planning and draw funds from respective departments. Do you think that this Strategy could be applied in our country as well in the near future? If not, why?
- 11. What is the typical cost range regarding the SWT your company provides?

The results of this investigation have been processed and are provided in Chapter 3 while they have been also used to cross check information found in literature, to depict the perceived barriers by the domestic industry in order to assess and include them in the overall barrier analysis and to cover the overall gap in literature regarding the status of the Hellenic SWT market.

In order to analyze the barriers to the establishment of an active Small wind turbine market in Greece, the barrier analysis framework of J.P Painuly was used (Painuly, 2001). The key concept in the framework analysis of Painuly is the fact that each barrier can be explored and analyzed at several levels where the depth of the analysis and details presented increase as the number of levels increase. The structure follows a top-down level approach, in which the top defines a broad category of barriers while lower levels provide more details and specific parameter characteristics. Specifically the identified levels may number from three to four according to the depth of the analysis (at a fourth level the dimension (depth and/or direction) of a barrier element can be explored):

- 1. Barrier Categories
- 2. Barriers
- 3. Barrier Elements
- 4. Barrier Elements dimensions

The advantages of such an approach are the facilitation of clarification of possible causes for the existence of a specific barrier and the in detail determination of barrier characteristics which could lead to the adoption of specific measures for their overcoming (Painuly, 2001). The framework can also follow a bottom up approach were the presence of a specific barrier component can justify the presence of a barrier category or barrier, thus aiding in the guidance of the conducted research.

Painuly identifies three possible manners of gathering information regarding RES barriers: Conduction of Literature Survey, Site Visits and Interaction with Stakeholders. Special notice is given to the last since this approach is most important for the identification of barriers from the perspective of stakeholders which are economically active within a specific country's regulations and limitations framework. Thus obtaining information which go beyond the boundaries of academic studies and originate from "first hand" experience is crucial. For this reason a separate chapter is provided which presents the most significant barrier categories and barriers as identified by the aforementioned survey conducted by the author of this thesis.

A number of barriers concerning RET have been identified in literature which range based on the specific technology or country of implementation characteristics. In general though the main categories in which they are divided include regardless of RET:

- Technical
- Cost Effectiveness
- Inconsistent Pricing structure
- Market
- Institutional
- Political
- Regulatory

In order to utilize the barrier analysis framework as presented but JP Painuly (Painuly, 2001) regarding Greece, the previously described country characteristics such as the favorable wind potential, market status, general electricity regime and current economic problems must be taken into account.

By selecting the barrier categories and barriers from the work of Painuly which are most suitable for the specific country and technology, Table 2 is constructed. Table 2 does not consist of all relevant levels, since barrier elements in depth analysis will be presented in according subchapters. Thus Levels 1 and 2, best suited for an analysis in the case of SWT in Greece, are hereby presented. Also the general barriers listed will be further explained and justified for the reasons of being included in the analysis.

Barrier Category (Level 1)	Barriers (Level 2)		
	Lack of information and awareness		
Market Failure /incolorfactions	Missing market infrastructure		
Market Fahure/Impleriections	High transaction costs		
	Poor market infrastructure		
Market Distortions	RET Taxes		
Market Distortions	Non-consideration of Externalities		
	Economically not viable		
	High discount rates		
	High payback period		
Economic and Financial	High Cost of Capital		
	High up-front capital costs for Capital		
	costs may also go up due to investors		
	Small market size		
	Unstable macro-economic environment		
	Lack of R&D Culture		
Institutional	Lack of a legal/regulatory framework		
monoulonar	Problems in realizing financial incentives		
	Clash of Interests		
	Lack of professional institutions		
	Lack of standard and codes certification		
	Lack of skilled personnel/training facilitie		
Technical	Product not reliable		
Teenmeur	Lack of O&M facilities		
	System Constraints		
	Lack of Entrepreneurs		
Social Cultural and Behavioural	Lack of consumer acceptance		
Social, Cultural and Denavioural	Lack of social acceptance		
Other	Uncertain government policies		

Table 2: Barriers categories and Barriers based on Literature (Painuly, 2001)

Based on the above literature based categorization framework, the analysis per barrier category will be presented in the according chapter specifically for the case of SWT in Greece.

1.5 Reading Guidelines

In Chapter 2 initially a review of different existing options within this technology along with their technological and economical characteristics will be presented in order for the reader to obtain all the necessary and up to date information regarding SWT as technological products so to be able to assess the later on analysis data regarding the related obstacles currently faced in Greece.

In Chapter 3, the Global status of this technology will be presented and continuing the Hellenic electricity generation regime along with relevant institutions and stakeholders will be described in order for the reader to understand the general framework within SWT will attempt to be established. Following, Hellenic SWT associated companies, products and policies involved will be identified and conclusions will be drawn regarding the technology's current market status. An economic analysis will provide with key parameters in order to assess the viability of a SWT investment and establish a basis for comparison to the competing technology of photovoltaic.

In Chapter 4, an investigation will be conducted regarding the obstacles and barriers faced by SWT in Greece, which will permit us to pinpoint the associated technological, economic-financial, institutional and socio-political bottlenecks, which do not allow this technology to further mature. The analysis will utilize the J.P.Painuly framework and will give insight on the role of the Hellenic Government in the past attempt of this niche market to expand.

Chapter 5 will synthesise the findings of previous sections with the aim to identify possible policy solutions to further the implementation of the technology and pinpoint in which ways its adoption by companies can be stimulated, with a special focus on how SWT ties in with a greater importance of corporate social responsibility in firms' decision making and performance. The analysis will conclude with a Table summarizing all the proposed action as derived from the whole of the chapter, categorized based on three main axes.

Chapter 6 will provide conclusions as well as reflections on the work conducted which will allow for the description of strong points of the thesis, limitations and difficulties encountered, novelties included in this work as well as proposed future research fields which could be based upon this Thesis.

2 Analysis of Technology

In this chapter the analysis regarding the key aspects of Wind Energy technology, ever focusing on urban implementation and Small Wind Turbines, will take place. This Chapter will build the required Engineering and Economic related knowledge which will familiarize readers in exactly understanding that SWT must not be treated as large scale wind energy but as machines of a similar but separate technological branch with its own limitations and considerations. Also it will include all the formulas to be used in further calculation of costs and other parameters required for the assessment of SWT as investments, it will present all the different types of turbines which are yet unfamiliar to the general public and will provides all the information required to understand in depth why certain technological trends have been established in this global market (such as Lift Driven Horizontal Axis turbines over Vertical Axis systems or Drag Driven machines). Furthermore, understanding the fundamental parameters which define this technology is critical in order for a sound assessment and description of obstacles originating from technical issues (which are in direct link to all other barrier categories) to be conducted later on. This analysis will start with the operating principles which hold for Small Wind Turbines. Following, the analysis will focus on the different design types and operating philosophies, along with the most important aspects of operation such as the SWT unique foundation and parts. Continuing, the wind distribution and methods of evaluating the wind potential of specifically urban areas will be presented. This analysis will lead to the realization of the current status of the technology, its advantages and limitations and will eventually conclude with the assessment of the economic aspects and cost of energy factors regarding Small wind turbines which will be used later on for the identification of related techno economic barriers as well as recommendations for their overcoming.

2.1 Operating Principles

2.1.1 General Aerodynamics

Wind can be considered as a flow of air particles or fluid elements which are defined by characteristic properties such as pressure, temperature, density, viscosity and velocity at each point of the flow. By introducing a stationary body of arbitrary shape into the flow, an interaction between the fluid elements and the "obstacle" in their way takes place that results in the creation of forces on the surface of the body. No matter how complex the body shape may be, these forces are created due to two basic sources: the pressure (p) and the shear stress (t) distribution over the body's surface. Pressure is defined as the normal force per unit area exerted on a surface due to the time rate of change of momentum of the gas (air) molecules impacting on that surface whereas the shear stress is created by frictional forces caused by the interaction of the moving gas molecules with the surface per unit area and acts tangential to the surface (Anderson, 2007). The net effect of the pressure and shear stress distributions over the complete body can be analyzed in a resultant force R and a moment M on the body. In turn the resultant force R can be analyzed based upon the angle between the airfoil and wind called *angle of attack*, into two components: Lift and Drag. Lift is the component of R perpendicular to the air flow (defined also as V_{∞} or infinite air

velocity) while Drag is the component of R parallel to the air flow which essentially represents the "resistance" of the body to the flow. Explanatory 2D Figures are presented below:



Figure 1: Pressure and Shear Stress Distribution (Anderson, 2007)



Figure 2: Net Force R and Lift and Drag components (Anderson, 2007)

By accordingly selecting the body's shape and its position relatively to the free air flow, the Lift component or the Drag component can be more accentuated and manipulated accordingly in order to be directed towards a preferred direction. These forces, which are called aerodynamic forces, can now move the body in space and provide the basic means to exploit the kinetic energy of the wind. Essentially the goal is maximizing the ratio of the Lift force over the Drag force which means having a higher value Lift than Drag. In the opposite case when the Drag exceeds the Lift the airfoil operates under *stall* which in most cases, except for control as it will be later mentioned, is unwanted operation.

As it can be implied by the above Figures the main body shape that is implemented in wind energy conversion systems, as expressed in two dimensions, is the streamline airfoil. As it will be further explained in following sections, this particular shape can essentially optimize the ratio between Lift and Drag in order to maximize the power extraction from the wind. Its basic geometric characteristics are presented in the Figure below, of which the most important one is the Chord or the distance between the Leading and the Trailing edge of the airfoil. As it can be seen from Figure 1, an angle between the cord line and the direction of the wind is formed which essentially describes the orientation of the airfoil to the wind. This angle is called angle of attack.



Figure 3: Airfoil Nomeclature (Anderson, 2007)

Based on the above, the Lift and Drag forces can be mathematically expressed in terms of the geometrical characteristics of the airfoil as:

$$L = \frac{1}{2}\rho V_{\infty}^2 C_L c \tag{2.1}$$

$$D = \frac{1}{2}\rho V_{\infty}^2 C_D c \tag{2.2}$$

Where,

 ρ is the density of the air, c is the chord and C_L , C_D are the non-dimensionalized Lift and Drag Coefficients respectively.

2.1.2 Modeling Theories

2.1.2.1 Blade element Theory

Apart from the free wind stream, rotating blades experience another air flow caused by their own rotational velocity. The concept can be easily understood if a person rapidly moves his hand, while no wind is blowing, across space. The "wind" experienced by wind turbines effectively alters the direction and magnitude of the relative wind velocity perceived by the blades. This *relative wind velocity* is now responsible for the creation of the aerodynamic forces. Blade element theory considers that the blade can be divided into a number of elements and that the forces on a blade element can be calculated by means of 2D airfoil characteristics using an angle of attack determined from the relative wind velocity in the cross-sectional plane of the element. The total aerodynamic force exerted on a blade and thus on a rotor can be derived from the forces exerted on all elements. The aerodynamic forces exerted on an airfoil can be further analyzed into different components thus yielding the forces which are responsible for the rotation of the wind turbine and the production of mechanical power. These forces are the out of plane of rotation *Thrust* and in plane of rotation *Torque* forces which are derived by the combination of Lift and Drag components and have a parallel and perpendicular to the rotor plane direction respectively. To easily explain the above, the following Figures are presented which show the derivation of these forces and their direction in space:



Figure 4: Vector Diagram Thrust and Torque Forces (Timmer, 2011)



Figure 5: Direction of Thrust and Torque (Timmer, 2011)

The produced aerodynamic and mechanical power can be now determined as:

$$P_{wind} = Thrust \cdot U(1-a) \tag{2.3}$$

$$P_{mechanical} = Torque \cdot \Omega \tag{2.4}$$

Also if the airfoil is considered as a free body the extracted power from the wind is equal to (Margaris, 2010):

$$P = \frac{1}{2}\rho U^3 A \frac{\Omega r}{U} (C_L - C_D \frac{\Omega r}{U}) \sqrt{1 + (\frac{\Omega r}{U})^2}$$
(2.5)

In order to maximize the above quantity, the term $\frac{\Omega r}{U}$ must become equal to (2/3) C_L/C_D . If now the power is non-dimensionalized by defining the ratio of the extracted power from the wind divided by the total power of the wind, the *power coefficient* C_P is determined. By considering the above, C_P reaches its maximum value when:

$$C_{P,Max} = (2/9)C_L(C_L/C_D)\sqrt{1 + (4/9)(C_L/C_D)^2}$$
(2.6)

The significance of the choice of airfoil characteristics is evident and now the role that the airfoil shape plays to the Lift-Drag ratio and conclusively in power extraction, as stated in chapter 2.1.1, is clear. The higher the C_L/C_D ratio, the higher the power extracted from the wind and the higher the electricity amount produced. This result gives rise to a logical question of what is the achievable overall maximum power coefficient or, stated differently, how much power can maximally be extracted from the wind. The answer, which will also define an important limitation of Wind Energy Technology, will be answered by the use of the momentum theory in the next chapter.

2.1.2.2 Momentum theory and Betz limit

The Momentum theory utilizes the concept of the actuator disk which has been previously explained. By using Figure 5 and equations (1.4), (1.5), (1.6) and by taking into account the energy, mass and momentum conservation the following formulations hold for the mass flow, thrust and power:

D

$$m = \rho U_1 A(1-a) \tag{2.7}$$

Thrust:

Mass Flow:

$$= m(U_1 - U_4) = \frac{1}{2}\rho U_1^2 A 4a(1 - a)$$
(2.8)

Power:

$$P = \frac{1}{2}m(U_1 + U_4)(U_1 - U_4) = \frac{1}{2}\rho U_1^3 A 4a(1-a)^2$$
(2.9)

If the power is non-dimensionalized, in order to derive the pressure coefficient, by dividing the above formula with the power of the free-air stream which flows though the same cross-sectional area without mechanical power being extracted from it, the following formula holds (Timmer, 2011):

$$C_P = P/(1/2\rho U_1^3 A) = 4a(1-a)^2$$
(2.10)

The maximum C_P , which can be theoretically be obtained is also called the *Betz Limit*. I can be derived by setting the $dC_P/da = 0$ which results in a=1/3. Eventually this yield:

$$C_{P,Max} = \frac{16}{27} = 0,59 \tag{2.11}$$

The maximum achievable value of the power coefficient is known as the Betz limit after Albert Betz the German aerodynamicist (Burton, Sharpe, Jenkins, & Bossanyi, 2001) and, to date, no wind turbine has been designed which is capable of exceeding this limit.

The above derivations and conclusions provide three fundamentally important facts for Small Wind turbines which also pose important limitations to their operation and implementation. These facts are:

- 1. The extracted mechanical power increases with the third power of the wind velocity. This non-linear relation of wind and power practically translates into "small reduction of wind speed-great reduction of extracted power" which is particularly important for machines operating under non-constant wind values, such as most Small wind turbines.
- 2. The extracted mechanical power increases as the cross sectional area of the rotor, which means when the area is a circle, the power depends on the square of the blade radius. This is an important limitation on wind turbine dimensions which essentially states that a turbines of small radius blades, inherently cannot extract high amount of power.

 No wind turbine can capture more than 59% of the kinetic energy of the wind. Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit (Burton, Sharpe, Jenkins, & Bossanyi, 2001).

2.1.3 The Power Curve

Eventually a wind turbine produces an amount of electrical power (Watt) according to its experienced relative wind velocity, which is a function of the free stream velocity. The curve which describes this correspondence is called the *Power Curve* and has the typical form of Figure 6. A wind turbine commences power production at a minimum so-called *cut in* speed and increases power production as the wind increases (Jamieson, 2011). When the wind speed reaches a particular value which is the rated value of operation where the electrical power output reaches is maximum limit, the turbine is controlled so that it produces this fixed amount of power called the rated power. When wind speed exceeds a limit, the *cut-out* speed, the turbine stops power production. At the wind speed region between the cut-in and the rated wind speed the rotational velocity is adjusted so that it follows the previously described Variable Speed Concept thus operating at maximum efficiency, while at the region between the rated and the cutout speed the turbine's rotational speed is fixed and the turbine is controlled in order to produce a constant electrical energy output, thus operating at below maximum efficiency (or a smaller C_P than the C_{P.max}).



Figure 6: Typical Wind Turbine Powe Curve (Rehman, 2012)

Through the description of the Power Curve, it can be understood that the smaller the cut out speed the faster the turbine will start producing power which will result in a increase in the overall power production of the turbine in its entire lifetime. Also the smaller the rated speed the faster the turbine will reach its maximum electrical power output limit. This realization is crusial for Small wind turbines which require a small cut-in and rated wind speed in order to compensate for small size and produce enough power in the urban wind environment.

2.2 Types of Turbines

2.2.1 Lift versus Drag

The history of wind power shows a general evolution from the use of simple, light devices driven by aerodynamic drag forces to heavy, material-intensive drag devices to the increased use of light, material-

efficient aerodynamic lift devices in the modern era. This evolution from drag to lift machines occurred due to the realization of the aerodynamic characteristic superiority of the latter, which enables lift turbines to reach close power coefficient values to the Betz limit. This realization is essential, especially in the case of SWT where space and dimensions are a limiting factor, since choosing Lift driven machines maximizes power extraction from the wind.

The reason why Drag driven machines are inherently inferior to Lift driven machines is the smaller attained aerodynamic force per same blade area (Gasch & Twele, 2012). If the power is considered as a function of the Drag, the area facing the wind and the relative velocity the following formulas hold for the Drag, power and power coefficient of Drag machines:

$$D = \frac{1}{2}\rho C_D (V_{\infty} - u)^2 a$$
 (2.12)

$$P = DA = \frac{1}{2}\rho C_D (V_{\infty} - u)^2 A V_{\infty}$$
(2.13)

$$C_{P} = \frac{\frac{1}{2}\rho C_{D}(V_{\infty} - u)^{2}AV_{\infty}}{\frac{1}{2}\rho V_{\infty}^{3}A} = \frac{u}{V_{\infty}}(1 - \frac{u}{V_{\infty}})^{2}C_{D}$$
(2.14)

By following the same analysis as in the derivation of the Betz limit, the optimum power coefficient can be obtained for $\frac{u}{V_{\infty}} = \frac{1}{3}$ and is equal to:

$$C_{P,max} = \frac{4}{27} C_D \tag{2.15}$$

Since the drag coefficient for a concave surface can hardly surpass 1.3, the $C_{P,max}$ can approximately become equal to 0,2.

Although the above result clearly illustrates the inefficiency of Drag driven machines, other reasons such as self-starting capability or high torque have allowed some designs to still exist today, especially with regard to Vertical Axis SWT. Nonetheless the vast majority of modern turbines are Lift Driven.

Before analysing different wind turbine designs and topologies the general advantages and disadvantages of Lift an Drag designs are summarized in Table 3 in order to provide an overview of the most important factors which govern their operation and insight on the reasons the Wind Industry has focus mainly on Lift Driven VAWT and HAWT.

	Lift HAWT	Lift VAWT	Drag VAWT		
Advantages	 Efficient Proven Product Widely used Most economical Many products available 	 Quite efficient Wind Direction immaterial Less sensitive to turbulence as HAWT Create fewer vibrations 	 Proven product (globally) Silent Reliable & robust Wind direction immaterial Can benefit from turbulent flows Create fewer vibrations 		
Disadvantages	 Do not cope well with frequently wind direction changes Do not cope well with buffeting 	1. Not yet proven 2. More sensitive to turbulence than Drag machines	1. Not efficient 2. Comparatively uneconomic		

Table 3: Advantages & Disadvantages of turbine designs (Wineur, 2007)

2.2.2 Vertical axis Wind Turbines

2.2.2.1 General Characteristics

Vertical Axis Wind turbines have been in the focus of scientific investigations regarding Wind Energy conversion systems for over half a century now. Unfortunately, since the 1980's they have been overthrown in industry and overshadowed in research, by their Horizontal Axis counterparts who essentially halted their future technological development and optimization. Nonetheless their unique operation and aerodynamics have retained an active interest in numerous dedicated academic clusters and possible advantages of VAWT over HAWT constitute them a more viable option for Urban Implementation.

The most prominent characteristic of VAWT is that they operate under any wind direction, i.e. are omnidirectional (Eriksson, Bernhoff, & Leijon, 2008). Thus a yaw mechanism that is necessary to the operation of HAWT, which can be costly and could be a source of failures, is omitted. This aspect is of particular importance to small scale wind turbines destined for the built environment, where wind can be multidirectional and turbulent. These machines have also the advantage of increasing their performance when operating under skewed flow whereas HAWT lose efficiency when the flow is not perpendicular to the axis of rotation (Mertens, Van Kuik, & Van Bussel, Performance of an H Darrieus in the skewed flow of a roof, 2003). Due to their simpler design (especially H Rotor type) VAWT could have lower manufacturing costs when produced at large scales than, their equivalent in terms of produced power, HAWT. Focusing on the blades, VAWT straight blades of constant geometry could be much less expensive than HAWT variable airfoil cross section ones.

The VAWT is also mechanically better able to withstand higher winds through changing stalling behaviour, offering a potential operational safety advantage during gust conditions (Howell, Qin, Edwards, & Durrani, 2010). Thus in areas where HAWT are unable to give reasonable efficiencies due to high wind and turbulence, VAWT can be used. Also they possess a low centre of gravity which can prove of

significance regarding the loading fatigue. Structurally maintenance can be significantly easier and of lower cost, since the generator, gear and main rotating/ supporting bearings are located close to the ground and not at higher altitudes. VAWT, when used for built environment applications, can have sun flickering problems. When they are within the direct path of sunrays and operating below 20 Hz, (Mertens, Van Kuik, & Van Bussel, Performance of an H Darrieus in the skewed flow of a roof, 2003) they can be a nuisance for an observer that will be close to the machine. This is not the case for VAWT which have a double blade passage between the sunrays and the observer.

Typical Vertical Axis Wind Turbine Model can be divided into the three categories:

- 1. Drag Force Driven Machines
- 2. Lift Force Driven Machines
- 3. Combination of the two previous

2.2.2.2 Drag Driven VAWT

In the first category of Drag Driven Machines the historically first design concept is the one of the Savonius Type Machine. Invented in 1929 by the Finnish Engineer S.J Savonius it is basically comprised by two half drum shaped structures fixed on a vertical axis of rotation that make use of the drag force to rotate each half drum face into the wind flow (Islam, Ting, & Fartaj, 2008). The Savonius Machine due to its operating philosophy and its proximity to the ground is limited to small maximum power coefficients and thus it is not suitable for power production operations unless the cost of reliability is much higher than efficiency. An advantage of Savonius turbine is the ability to self-start and thus it can be also used in a hybrid form along with other types of Lift Driven Machines to provide self- starting operation.



Figure 7: Commercial Savonius Machine (Focus Technology Co., Ltd., 2013)

2.2.2.3 Lift Driven VAWT

In the category of Lift Driven Vertical Axis Wind Turbines exist two main designs; the Darrieus Troposkien (commonly also referred to as "Eggbeater") and Straight blade or H Rotor type machines. Both invented and patented in 1931 (Paraschivoiu, 2002) in the USA by French engineer George Jeans Mary Darrieus they remain till today the most commonly used VAWT designs, after having undergone considerable research and engineering development. These machines use the aerodynamic lift force produced upon the blades by the free wind stream to rotate the central axis or mast at rotational speeds capable of driving generator turbines to high RPM. The typical configuration includes two or more blades attached to the main vertical axis that is connected to a gear box and a generator located near to the ground level. Although superior to Drag Driven Machines, the Darrieus Machines suffer from low starting torque, difficulties in construction, structural issues and poor building integration (Eriksson, Bernhoff, & Leijon, 2008). More analytically at low rotational speeds and hence low tip speed ratios, the Darrieus rotor has a high average absolute angle of attack which causes essentially the blades to stall. Thus a low Lift force compared to a high Drag force produced during start up, make the self-start of these machines difficult to impossible (Mertens, Van Kuik, & Van Bussel, Performance of an H Darrieus in the skewed flow of a roof, 2003). At higher rotational speed such a problem ceases to exist.

The *Troposkien* (from the Greek roots: $T\rho\sigma\pi\eta$, turning and $\Sigma\chi\sigma\nu\eta$, rope; "turning rope") design (Figure 8) includes curved shaped blades, for the minimization of bending moments and stresses due to high centrifugal loads, which approximate the shape of a perfectly flexible cable, of uniform density and cross section, hanging freely from two fixed points (Paraschivoiu, 2002).



Figure 8: Eggbeater Darrieus Turbine (Universiti Malaysia Perlis, 2013)

The *Straight Bladed* Darrieus rotor also commonly referred to as "H- rotor" and its variations, the "Giromill" and "Cycloturbine", is the second and most interesting with regard to the small-scale wind turbine market, design concept of the Lift Driven Vertical Axis Wind Turbines. Its main difference though from the Troposkien design is the straight shape of the blades that are connected by struts to the Mast.

This design difference, although it facilitates the overall manufacturing process of the turbine, could also introduce the problem of partially decreasing the rotor's $C_{P,max}$ since drag forces could be introduced by the struts and because blade tip vortices could reduce the overall lift force. The Cycloturbine variation allows the blades to rotate around their own axis which essentially introduces some angle relative to the wind direction and thus "pitches" the blades. Also this effect can provide self-starting capability, in contrast to the other variations where a motor is required to initially rotate the turbine until it reaches rotational velocities when it can be driven by the wind.



Figure 9: Eggbeater, H-Rotor and Cycloturbine (Wineur, 2009) (Electron Solar Energy, 2011) (Cleanfield Energy, 2013)

2.2.2.4 Other Concepts

The final category includes designs that have attempted to incorporate the advantages of Drag and Lift Driven Machines in order to overcome limitations and design problems or have altered the existing designs in order to maximize performance according to the progresses in the field of fluid dynamics.

In the first case, the combination of the Savonius rotor ability to self-start with the high efficiency provided by the Darrieus Rotors configurations is the main goal. The majority of these machines have not been investigated as thoroughly as designs from the other two categories. As suggested by various researchers the power coefficient of such machines can reach values of up to 0,35 for different overlap percentages. Further study is required to show the validity of these results for large scale commercial applications (Bhutta, Hayat, Farooq, Ali, Jamil, & Zahid, 2012).



Figure 10: Lift-Drag Turbine (R & S Windenergy GmbH & Co. KG, 2013)

In the second category, the advances in hydro dynamics and the creation of the Gorlov Helical Turbine by Professor Alexander M. Gorlov of the North-eastern University (Khan, Bhuyan, Iqbal, & Quaicoe, 2009) led to the introduction of helical blades in the gyromill design while operating under the same physical principles. This design evolution addressed torque ripple issues since the blades "curve" around the axis of rotation so in each revolution of the turbine there is at each instant a foil section at each possible angle of attack. This continuity solves the problem of abrupt angle variation and thus abrupt lift and drag force distribution which caused torque, vibration and noise issues (Gorlov, 1998). Most modern and technologically advanced VAWT have incorporated this design with the down side of introducing higher manufacturing costs than other turbines. Figure 11 presents the aesthetically attractive and technologically advanced Quietrevolution© QR5 turbine on site and while undergoing testing at a wind tunnel facility.



Figure 11: Quietrevolution qr5 helical blade wind turbine (Quiet Revolution Ltd, 2012)

2.2.3 Horizontal Axis

Horizontal axis wind turbines (HAWT) are currently the most well-known and implemented machines in both Urban and Large scale wind energy production. Historically this design has proven its endurance and today it is synonymous with the production of wind energy of small or large scale. HAWTs have been established as the modernized version of windmills and as an icon for renewable energy technologies in general. Unlike Vertical axis wind turbines, HAWT are entirely Lift Driven employing the most advanced airfoil shaped blades for the maximization of power extraction. Thus no differentiations based upon the core physical phenomena which rule power extraction exist. Instead they can be primarily divided in whether they operate *Upwind* or *Downwind* and the way they orientate with regard to the wind direction and secondary based on the number of blades they employ. Figure 13 presents the types of HAWT with respect to the first factor. The blades rotate around a vertical axis lying parallel to the ground. A tower is needed to elevate the rotor in order to take advantage of stronger winds and to also provide an axis of rotation for the orientation of the turbine with the wind or yaw. Apart from the blades, the generator is located above ground, inside a cover housing called the *nacelle*, along with any other electromechanical part.



Figure 12: Upwind Horizontal Axis Small wind turbine (New Home Wind Power, 2012)



Figure 13: HAWT concepts based on rotor's relative position with the wind (from left to right): upwind type with active yaw; upwind type with passive yaw; downwind type with passive yaw (Beller, 2009)

Most HAWT implement three symmetrical blades rigidly joined to the axis of rotation via a supporting structure, which can allow pitching movement, called the *hub*. Although this design has been proven to work effectively, it is not the only possibility nor the most aerodynamically advanced. Figure 14 presents the different types available with respect to the number of blades used. Nonetheless lower mechanical fatigue, symmetry in experienced aerodynamic loads resulting in smooth operation while yawing (Manwell, McGowan, & Rogers, 2002) and visual symmetry which provides higher aesthetic appeal to the public, have established this design as the predominant one. More blades require a smaller tip speed ratio for the same power production when compared to less blade turbines. This is an important factor especially for SWT since it translates into smaller rotational speeds or rotating tip speeds which has a direct effect on noise. Hence three bladed turbines can be considered "quieter" than other designs



Figure 14: HAWT concepts based on number of blades (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004)

2.3 Additional Small Wind Turbine Considerations and Parts

Wind turbines designed for the Urban environment can either be installed directly on rooftops or the can be installed on space next to buildings. The location of installation depends upon the size and weight of the turbine which in turn depends on its type, application and eventually the power output. Thus depending on the above factors, different parameters are to be taken in consideration with regard to the mounting equipment, the structural loads and the needed parts.

One of the most important parameters is the height of the tower which will either house the blades and generator on top of it (HAWT) or will act as an axis of rotation (VAWT). The general consideration is the higher the tower, the better the quality of the wind (low levels of turbulence) which will result in a more efficient and smooth turbine operation. Nonetheless the higher the tower, the more material will be needed to endure all gravitational and aerodynamic forces so as to ensure a safe construction. More material directly has effect on the overall weight. If the turbine is to be located on ground next to buildings where weight is of less importance than maximizing power production, the tower can reach up to 25 meters in order to avoid the induced turbulence introduced by trees, buildings and other constructions (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004). On the other hand if a turbine is to be placed directly on a rooftop, the permissible height will be practically limited by the weight of the tower since structural safety and vibration issues are of higher importance than maximizing power production. Most rooftop installed HAWT employ 5 to 8 meter steel or other material poles. According to the choice of location and height of the tower, the according foundation equipment must be chosen. In the case of rooftop mounted turbines, the pole must be bolted on the roof or an walls perpendicular to the roof area(Appendix) and additional guy-wires or struts may be used to further increase the stability and decrease vibrations (Figure 15 left). If the wind turbine is to be located on the ground, steel reinforced concrete bases or blocks are required. In both cases the structural loads and bending of the tower must be minimized.



Figure 15: Different tower designs (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004)

The need for lighter constructions directly affects other parts of the turbine such as the gear box, braking mechanism, generators and alternators which are located in the nacelle (HAWT) or on the ground level (VAWT). All parts are required to have minimum dimensions while reaching high electricity generation and operational efficiencies. Of the above parts the most important regarding SWT turbines is the generator since its type choice can eliminate the need for a gear box and even a mechanical break, thus resulting in a simplified, reliable and efficient design. The most common generator types (Abarzadeh, Kojabadi, & Chang, 2011) that can be used in small wind turbines are:

- 1. Direct drive permanent magnet synchronous generators
- 2. Self-excited asynchronous generators with gear box
- 3. Permanent magnet synchronous generators with gear box

Contrary to large scale wind energy farms (where HAWT have become the norm), still a major consideration on the implementation of SWT is the type of wind turbine to be used. The advantages and disadvantages of all types of turbines, either operating with Lift or Drag and rotate over the Vertical or horizontal axis of rotation have been previously described along with the unique technological features of each type. Based on a study of World Wind Energy Association (WWEA) on 327 commercial small wind turbine manufacturing companies, as of the end of 2011 the dominant choice was the HAWT design, which was invested on by 74% of manufacturers while VAWT design, hybrid and other designs were preferred by an only 18%, 6% and 2% percentage. Figure 16 presents graphically the result of this study.


Figure 16 : Orientation preference of small wind turbine manufacturers (World Wind Energy Association, 2013)

Overall the technical characteristics identified by the WWEA report per turbine type are summarized in Table 4 and Table 5. It can be determined that over the different type models, VAWT present a higher percentage of turbines with a rated power lower than 10kW and 5kW. According to the same report, this trend in manufacturing corresponds well with the current worldwide market demand.

Table 4: Small VAWT Statistics Worldwide (World Wind Energy Association, 2013)

VAWT Statistics				
Total Number of VAWT Manufacturers	60			
Total Number of VAWT Models < 100 kW	157			
Percentage of turbines $\leq 10 \text{ kW}$	88,50%			
Percentage of turbines $\leq 5 \text{ kW}$	$75{,}80\%$			

Table 5: Small HAWT Statistics Worldwide (World Wind Energy Association, 2013)

HAWT Statistics				
Total Number of HAWT Manufacturers	242			
Total Number of HAWT Models $< 100 \text{kW}$	717			
Percentage of turbines $\leq 10 \text{ kW}$	$78,\!10\%$			
Percentage of turbines $\leq 5 \text{ kW}$	$66,\!20\%$			

2.4 Wind Characteristics

At altitudes up to 100 meters, the ground's roughness as well as other obstacles essentially slow down the prevailing wind due to friction and result in a logarithmic relation between altitude and wind velocity. The change of values of the velocity, which varies from 0 to infinite free wind speed, takes place inside a part of the atmosphere. This area forms the *atmospheric boundary layer*. This logarithmic relation can be expressed by the log-law which holds accurately for low roughness areas. In bibliography this relation is also characterized as *Wind Shear* (Mathew, 2006)and is equal to:

$$V(h) = V(h_{ref}) \left(\frac{\ln(h/z)}{\ln(h_{ref}/z)} \right)$$
(2.16)

Where,

V is the wind velocity, h is the height measuring the velocity, h_{ref} is a reference height and z is the surface roughness.

According to the landscape, the log law can give different velocity distributions. In open areas or at sea, the velocity will increase more smoothly with height but in areas with high roughness, such as cities or inhabited areas near forests, the velocity profile changes significantly and an internal boundary layer is formed. Figure 17 presents this change.



Figure 17: Step change in velocity profile when introducing roughness (Beller, 2009)

Apart from surface roughness, natural or man-made obstacles introduce turbulence to the wind heading downstream and effectively decrease its speed significantly. Turbulent air, in its turn, introduces mechanical stresses on the orientating mechanisms of wind turbines (yawing) and decreases the power coefficient, which translates in decreasing the amount of extracted energy by the aerodynamic rotor. If a flat terrain with no change in surface roughness is considered (Figure 18) the effect of introducing a manmade obstacle on the wind velocity profile is considerable. At 5hs or at a vertical distance of five times the height of the obstacle, the velocity can decrease to up to 43%. This effect also stresses the significance of employing high towers for SWT for positioning the rotor facing winds of higher velocities and of less turbulence. Also the distance downwind from an obstacle is an important factor, since the undisturbed wind reaches its initial velocities prior to the obstacle and power losses become small, at a vertical distance equal to more than 15hs or fifteen times the height of the obstacle. Thus in the case of a SWT not placed on a roof but on the ground next to buildings, the distance from buildings and other obstacles must be maximized in order to maximize performance and minimize losses.



Figure 18:Speed, power and turbulence effects downstream of a man made obstacle (Manwell, McGowan, & Rogers, 2002)

If both the effects of surrounding roughness and existence of obstacles is considered it can be understood that the local wind regimes have more complex characteristics and are influenced by local parameters. Thus they cannot be easily predicted by average wind speeds over an area or average characteristics of the roughness alone.

The Urban environment of densely cities introduces specific challenges for the implementation of wind turbines mainly due to the interaction of the undisturbed wind with buildings and the way they are arranged. Building heights range in size and their position can affect the wind speed downwind as discussed in the previous section. Besides this effect, when buildings are arranged in line across streets they also introduce the phenomenon of *Urban or Street Canyoning* which alters the velocity profile and further slows free wind speed down (Beller, 2009). Figure 19 explains this phenomenon. When wind streams of perpendicular direction to that of the "street canyon" approach, they create vortices which introduce turbulence across it and eventually decrease the efficiency of turbines located on top of buildings forming the "canyon".



Figure 19: Urban Canyon and effect on velocity profile (Beller, 2009)

In the case where street canyoning is avoided, the building can have a different effect on the wind speed and in some cases it can even enhance the power productivity of some turbine types. As researchers have indicated, average wind speeds are much higher at rooftops of high story buildings, when compared to small undisturbed wind speeds in the built environment. Furthermore the upwind side of tall buildings due to its interaction with the air flow essentially alters the direction of the wind from being parallel to the horizontal rooftop to being in angle with it (Figure 20). This angle is called *Skew Angle* and the air flow is characterized as *Skewed Flow* (Mertens, The energy yield of roof mounted wind turbines, 2003).



Figure 20: Skewed Flow (Mertens, Wind Energy in the Built Environment, 2005)

2.5 Calculating the Annual Energy Production

In order to calculate the energy production of a wind turbine, above all parameters, the wind regime at the site of installation must be taken into account. Site specific wind velocity measurements can prove to be a difficult and time consuming (up to one year) task, which if not performed by following standardized procedures, may introduce unreliability's and produce an overall incorrect result regarding the wind speed probability distribution. In order to accelerate the procedure of estimating the above factors, it is most common to use a specific statistical tool for the realistic representation of the probability of occurrence of a specific wind speed. The statistical distribution used is the *Weibull Distribution* (Bussel, WIND ENERGY ONLINE READER, 2008).

The Weibull distribution is used for the characterization of 10 minute average wind speeds and produces a close result to the one obtained by detailed measurements as presented in a histogram graph (Figure 21). The mathematical expression for the probability density factor is equal to:

$$f(V) = \frac{k}{V} \left(\frac{V}{a}\right)^k e^{-\left(\frac{V}{a}\right)^k}$$
(2.17)

Where,

V is the wind velocity, k is the shape parameter and a is the scale parameter

The scale and shape parameters are chosen according to the site's characteristics in order for the distribution to be as representative and realistic as possible. Also the scale parameter is linked to the yearly average wind speed by the following formula (Timmer, 2011):

$$a = \frac{V_{avg(year)}}{0.89} \tag{2.18}$$

Where,

 $V_{avg (year)}$ is the average yearly wind velocity

The shape parameter can also be linked to the mean wind speed and the standard deviation of wind speed by the following formula (Manwell, McGowan, & Rogers, 2002)

$$k = \frac{\sigma_{\nu}}{V_{avg(year)}} \tag{2.19}$$

Where,

 σ_v is the wind speed standard deviation and $V_{avg (year)}$ is the average yearly wind velocity

The Cumulative Distribution Function (CDF) of the Weibull Distribution is equal to:

$$F(V) = 1 - e^{-(V/a)^{k}}$$
(2.20)

Where,

V is the wind velocity and a is the scale parameter



Figure 21: Weibull distribution from 10 minute wind data (Timmer, 2011)

Having determined the power curve characteristics for a specific wind turbine, and having determined the Weibull distribution of wind velocities the annual electrical energy yield can be calculated as follows:

$$E = T \cdot \int_{V_{cut-in}}^{V_{cut-out}} P_{el}(V) \cdot f(V) dV$$
(2.21)

Where,

T is the is equal to the hours per year, which is 8760hr, V_{cut-in} is the cut in wind speed, $V_{cut-out}$ is the cut out wind speed, f(V) is the Weibull distribution and $P_{el}(V)$ is the electrical power output which is calculated as:

$$P_{elec} = (1 - BL) \cdot P_{aero} - PDL \cdot P_{aero max}$$

$$(2.22)$$

Where,

 P_{aero} is the electrical power output, BL is the base losses (a constant value, only depending on the rated aerodynamic power), PDL are power dependent losses

Having determined the annual energy yield an important parameter can be defined: the *Capacity Factor*. The capacity factor is defined as the ratio of the actual annual output, to its potential output if it were possible for a wind turbine to operate at its full nameplate capacity indefinitely. The mathematical expression is given by equation 2.23:

$$CF = \frac{E_{annual}}{E_{rated power}}$$
(2.23)

Where E_{annual} is the energy yield calculated by (2.21) and $E_{rated power}$ is the energy yield produced if the wind turbine operated constantly at rated power output.

The capacity factor definition can be extended if the *availability* of the turbine is considered The availability is expressed as the fraction of the time in a year which a turbine is able to produce electricity. The time when a turbine is not operating for scheduled maintenance or unscheduled repairs essentially decreases the amount of produced energy. Thus if the E_{annual} term in equation 2.23 incorporates the fraction of availability, the Capacity Factor is expected to produce a lower value, representing more realistic results.

2.6 Economic Aspects of Wind Technology

2.6.1 General wind energy economic aspects

Wind Energy in order to be a viable and competitive option for energy production, as compared to conventional non-sustainable fossil fuel based technologies, apart from employing technologically advanced and durable machinery it must be able to result in an overall economic benefit for the end user. Effectively this means Wind turbines (regardless of scale and power output) represent, apart from an environmentally beneficiary and ethically correct energy production choice, a profit-driven investment (Manwell, McGowan, & Rogers, 2002). The ability of producing as much possible electricity in a sustainable manner while being cost-effective, thus, is a crucial factor for their success. Currently Wind turbines still rely on subsidies and support from governmental policies in order to achieve the desired cost-effectiveness since they represent a relatively expensive investment when compared to conventional energy producing methods. Nonetheless, advances in technology, mass production (economy of scale) and the realization of the importance of accounting the external costs (i.e. the damage to the environment in the form of monetary cost) originating from conventional power generation methods promise a future where support will no longer be needed. More information about the non-accounting of external costs and other forms of barriers faced by wind Energy will be presented in the according following chapter. Essentially the main goal (from an economic perspective) of any energy producing system is the market value of produced energy to exceed costs. Market value and costs are thus two governing factors which need to be maximized and minimized accordingly, in order for an investment to be attractive. They in turn consist of a number or parameters, which for the case of Wind Energy technology are presented in a summarized form in Figure 22, below. In the following paragraphs a more detailed description of these general concepts and elements will be given in order to eventually focus on the key economic factors which are of importance for the implementation of Small wind turbines.



Figure 22: Different Wind Energy economic aspects (Manwell, McGowan, & Rogers, 2002)

The market value of wind energy systems, as analyzed by Manwell, McGowan, & Rogers, is generally comprised by two main components which essentially describe two different forms of potential revenue and benefit. The first component regards the savings or avoided costs which will result by the use of wind energy rather than the most likely alternative energy source and the second regards the quantified and monetized environmental benefits (such as reduction of COx, NOx and SOx gas emissions) from the use of wind energy as compared to the use of conventional energy producing methods. Furthermore, the first type of avoided-cost-based revenues can be described as the total potential amount of revenue which can be received by either saving/decreasing the overall cost of electricity consumption (from an end user perspective) and saving/decreasing the use of conventional fuel (from an energy producing company perspective) via using or consuming the wind turbine generated energy or by selling the produced energy to the utility grid at a price which reflects the above described avoided costs. Regarding the second type of monetized environmental benefits, they can be expressed by the number of financial incentives and governmental policies, such as tax reliefs, renewable energy certificates, guaranteed above market selling prices or "feed-in-tariffs", which aim at promoting the adoption of RET technologies and in doing so provide an indirect revenue. In this type the profit is not obtained by the manner the producer(s) chooses to manage the produced energy but rather is obtained by the initiative of governments to "reward" the choice of producing energy via the sustainable and renewable means employed by Wind energy technology, considering the overall environmental benefits of this choice.

It is worth mentioning that a number of environmentally associated benefits exist which cannot be yet accurately quantified in monetary terms and thus cannot be directly considered a form of revenue. Such benefits, which can also be included in the general group of "social costs of energy production", may for example include the health benefits obtained by the reduction of emissions or by the replacement of fossil fuel operated power plants.

Apart from these previously mentioned "sources" of revenue, other methods to benefit from the adoption of wind energy systems can be identified. One of the most interesting cases, further to be analyzed in the following section regarding SWT is the opportunity presented to corporations to promote and advertise their Corporate Social Responsibility role. A projection of a social and environmental responsible company profile can result indirectly to higher profits from increased sales. This fact is due to the willingness of consumers to purchase products at marginally higher prices or prefer to buy products from specific companies when they are aware of them being socially responsible.

The costs of wind energy systems can range according to the scale and application but overall are affected by similar parameters and are a function of the turbine's *lifetime* or the estimated time period of operation. The lifetime is usually considered as the economic lifetime of the system and for most wind turbines ranges from 20 to 25 years according to type and operating conditions (Bussel, WIND ENERGY ONLINE READER, 2008). Costs can be based upon physical aspects of wind energy conversion, such as the wind energy regime of a particular area, machinery aspects such as the efficiency, design and materials used for the turbine and on parameters such as the financing/subsidizing of the project. A major difference to conventional fossil fuel based energy production methods is that Wind Energy does not depend on fuel fluctuating prices and costs since the "fuel" (wind) is for free.

Overall the main costs can be divided into *upfront* and *variable/running* (Stancovic, Campbell, & Harries, 2009). The upfront costs are dominated by the investment costs of the turbines (purchase or development) but also include the component transportation and installation, land renting (regarding large sale turbines), construction of foundation, electrical parts installation (such as cabling and electronic equipment), connection to the utility grid, insurance and administration costs (in the case of large sale systems), and techno economic consulting costs. The latter, although it introduces smaller in monetary value costs than the rest of the parameters, is of particular importance since it includes the determination of the wind regime or wind-mapping, the type of turbines to be used and the location of the energy system's position which if not correctly determined can lead to further indirect costs.

Additionally the administrative, legal and financing costs can be considered as upfront costs (Morthorst, Krohn, & Awerbuch, 2009). Especially for the case of financing, usually a purchaser or developer will down pay a small part of the previously mentioned costs and finance the rest by loaning. The total cumulative interest from the loan over the lifetime of the turbine or project can add up to a significant amount of the total cost (Manwell, McGowan, & Rogers, 2002), which can be accurately calculated before the investment. Finally depending on the existing institutional setting, environmental impact assessments and other development costs. Regarding the variable costs, they are mainly expressed by the operation and maintenance costs. Some components of O&M costs can be easier to estimate but others such as repairs and substitution of spare parts prove difficult to predict.. O&M costs are further categorized as being periodic (planned) or unscheduled. The first category proves to be unrelated to the level of the turbines operation while the second, as described above, is directly related to the amount of operation. This differentiation essentially constitutes periodic O&M costs as fixed and thus they could also be regarded as upfront costs. To summarize the above, Table 6 is presented below:

Wind Energy Costs			
Upfront Costs	Variable costs		
Turbine (ex works)	Unscheduled service		
Transportation	Spare part replacement		
Foundation	Incidence of failure		
Financial costs	-		
Electric installation	-		
Grid connection	-		
Consultancy	-		
Periodic O&M	_		
Land rent	-		

Table	6:	Wind	Energy	Costs	per	type
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Figure 23: Upfront Costs Percentages of Total Cost

As stated in the European Wind Energy Association's 2009 report regarding the economics of wind energy (Large scale turbines), approximately 75% of a Wind Energy system's costs are related to upfront costs while O&M costs for new turbines are estimated to 20-25% of the total Levelized cost. It must be noted that O&M costs annual costs range between 2-3 % of total costs (European Wind Energy Association, 2009). Thus the implementation of Wind Energy technologies requires capital-intensive investments as compared to conventional fossil fuel operating technologies such as a natural gas power plant, where as much as 40-70% of costs are related to fuel and O&M.

2.6.2 Economic Models

In order to address and quantify benefits, several economic analysis methods, which take into account the above factors, exist. These methods according to the complexity of included parameters and general approach can aid to determine the economic performance of wind energy systems and estimate their viability. Depending on the scale, application and end goal of the implemented wind energy system different parameters are evaluated or the same parameters can have a different weight factor. Eventually the determination of the above will lead to the choice of economic model best suited for the evaluation of the system.

The most commonly used economic analysis techniques for Wind Energy systems include either *Simplified methods* or *Life-cycle cost methods* which have their own definitions on economic parameters (Manwell, McGowan, & Rogers, 2002). Due to their particular advantages and disadvantages, their suitability and accuracy depends on their nature of the system's scale, operation and end goal. These methods and their according models which comprise them will be further explained in the next paragraphs in order to be able to evaluate their use for the case of Small wind turbines in the following chapters.

Simplified methods aim to provide quick and easy to calculate formulations in order to determine a systems benefits without taking into account complex economic variables and relations or the time value of capital which is related to the lifetime of the system. Thus they can be considered as the preliminary step

in realizing whether an investment can provide benefit and be considered as cost worthy. Two such methods which are frequently used include the *simple predicted payback* and the *cost of energy* (COE).

The simple predicted payback method calculates the period of time (years) for which the wind system will produce as much revenue to equate the initial capital cost of the investment by taking into account the ratio of the total capital cost and the average annual return of the system. The latter is a function of the amount of energy produces and the price of electricity. The formulas which express the above are the following:

$$Payback Time = \frac{Installed Capital Cost}{Average Annual Return}$$
(2.24)

Average Annual Return =
$$P \cdot E$$
 (2.25)

Where,

P is the price of electricity (\notin/kWh) and E is the annual energy production (kWh/year).

The simplified Cost of Energy (COE) approach calculates the cost per kWh (\notin /kWh) of a wind system by dividing the sum of the capital cost multiplied by an average annual charge factor (FCR) accounting for utility debt, equity costs, taxes and insurance and annual maintenance cost (hence the total operating cost) with the annual energy production. The corresponding equations are:

$$COE = \frac{(Capital \ Cost \cdot FCR + Annual \ Maintenance \ Cost)}{Annual \ Energy \ Production}$$
(2.26)

Where,

FCR is the fixed charge rate factor.

The above calculation results in an estimation of the cost per produced kWh if all parameters are kept constant in time. Since this does not accurately reflect reality, when more detailed calculations are required, Life-cycle methods are used. Nonetheless the simplified COE can immediately provide the means to approximately compare the cost of the wind energy system with a competing source (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004).

Finally the simplified Generation Costs, which essentially represents an indication to the costs required to develop and operate a RET project per kWh produced during the entire lifetime of the project (ϵ/kWh) , can calculate the price per kWh when using wind energy systems (altenergymag.com, 2013). The according formula is equal to:

$$Generation Costs = \frac{Capital Costs}{Lifetime Energy Production}$$
(2.27)

Life-cycle methods take into account time-varying cash-flows and refer to them to a common point in time allowing for an accurate comparison with other energy producing methods (Manwell, McGowan, & Rogers, 2002). The value of a set amount of money is in function with the rate of interest. Even if inflation

was not considered as a parameter, since any amount of money can be invested and bear interest, the overall result is that its value will not be the same in the future. The current value of a fixed amount of money is defined as the Present Value (PV) and is linked to its Future Value (FV) via an interest or discount rate, r.

The cost of a wind energy system investment represents an amount of money which changes in value over the lifetime of the system. The present value of cost (or the value of cost at the time of the investment) will be associated with its future value at any given point in time of the system's lifetime, based upon r (Harris & Roach, 2007). The equation which describes this relation is defined as:

$$PV_c = C_t / (1+r)^t (2.28)$$

$$1 + r = (1 + i)/(1 + v) \tag{2.29}$$

Where,

PV is the *Present Value of Cost*, C_t is the value of cost in year t, and r is the *Nominal* or *Real* interest rate which is a function of i -the interest rate- and v -the inflation rate-.

When costs or revenues which occur at unequal time intervals are present, they are often expressed as equivalent equal "payment" at regular time intervals. This method is called *Levelizing* and can be used to take into account the discount rate for each equal payment per time interval. If the lifetime of the wind system is considered to be N years, Levelizing is performed on Costs and C represents yearly costs during the lifetime of the project, then the sum of every relevant present value can be expressed as:

$$NPV_c = \sum_{t=1}^{N} C\left(\frac{1}{1+r}\right)^t$$
 (2.30)

Formula 2.24 represents the Net Present Value of Cost (Manwell, McGowan, & Rogers, 2002), which is an economic tool to assess different investment options and essentially adds every annual future cost back to the first year of the investment thus providing the total cost for the lifetime of the system. It follows that investments with the lowest NPV_c are considered to be the most economically attractive. Net Present Value can be also considered for the more general case of cash inflows minus cash outflows (revenue-costs). When NPV is over zero the investment can be classified as worthy whereas if NPV is less than zero the investment is not cost-efficient. Finally in the case of NPV equal to zero the decision for the investment should be based on different criteria.

By using the concept of Levelizing, the *Levelized Cost of Energy* can also be defined as the sum of annual Levelized costs of a wind energy system over the annual energy production.

$$COE_{L} = \frac{\sum (Levelized Annual Costs)}{Annual Energy Production}$$
(2.31)

By taking into account equation 2.24 and by expressing the annual energy production NPV_E , the above equation can be linked with the NPV_C and NPV_E (in general form) as:

$$NPV_E = \sum_{t=1}^{N} E/(1+r)^t$$
(2.32)

$$COE_L = \frac{NPV_C}{NPV_E} \tag{2.33}$$

In this basic form the previously mentioned simpler method for calculating the Cost of Energy can be further expanded to include the time value of money.

Another corresponding economic potential evaluation tool which again calculates the costs in terms ϵ/kWh is the *Levelized Production Cost (LPC)*. LPC is based on COE_L and defined as (Timmer, 2011):

$$LPC = \frac{\sum_{t=1}^{N} (C(t) - R(t))(1+r)^{-t}}{\sum_{t=1}^{N} (E(t))(1+r)^{-t}}$$
(2.34)

Where,

C(t) is the Cost, R(t) is the revenue, E(t) is the energy production, as a function of year t and r is the interest rate.

According to IEA standards (Bussel, Course Introduction to Wind Energy AE3-W02 2011-2012, 2012), LPC can also be rewritten as:

$$LPC = \frac{I_{tot}}{aE_y} + \frac{TOC}{Ey}$$
(2.35)

$$a = \sum_{t=1}^{N} (1+r)^{-t} = \frac{1}{r} \left[1 - \left(\frac{1}{1+r}\right)^{N} \right]$$
(2.36)

Where,

 I_{tot} is the total investment costs, α is the annuity factor, Ey is the yearly energy yield and TOC (Total other Costs) is the average yearly O&M costs (held constant) and N is the economic lifetime.

A tool often used to assess the profitability of an investment is the Internal Rate of Return (IRR), which essentially evaluates the rate of return, r, which makes the NPV of all cash flows equal to zero. Utilizing IRR for the evaluation of a wind energy system requires an initially negative but subsequently positive cash flow stream in order for a correct result interpretation to be acquired. It follows that a higher IRR rate is more desirable since it represents an investment with a greater rate of return which essentially "breaks even" faster than an investment with a lower IRR. IRR does not show how profitable an investment will eventually be as is the case with NPV calculations. For such reasons small projects with high IRR of which negative to positive cash flows become equal sooner, may misleadingly appear more attractive than large projects with lower IRR's which in the course of time may generate more revenue (McKinsey & Co., 2004). Nonetheless a high IRR and thus a faster recouped initial expenditure indicates a safer and thus more attractive investment.

2.6.3 SWT differences

Although the previously mentioned methods hold for large scale Wind farms and small scale SWT alike, the separate factors which govern the cost-effectiveness of the implementation of wind energy on each scale can vary. Also methods which can be effective for large scale implementation can be regarded as insufficient or misleading for small sale operation and vice versa. These differences will be presented in the following sections.

A rather obvious difference between SWT and Large scale Wind Farms is the number of turbines implemented at each scale. Wind Farms employ a significant number of turbines usually obtained from the same manufacturer whereas in small scale applications, the implementation of a single turbine is the norm. Moreover, in Wind Farms, turbines are consisted of a substantially larger amount of components due to their higher degree of technological complexity. In SWT the design is often preferred to be as simple and rugged as possible and with the minimum number of moving parts in order to reduce the production costs and provide easy installation, maintenance and consistent reliable operation. Thus it follows that the principles of economy of scale apply more to the first case for both the turbine as a whole and its separate parts rather than the second. This fact has a significant effect on the upfront costs to be paid in each scale respectively. Also regarding the operation and maintenance costs, small wind turbines are generally more expensive than larger wind turbines relative to the amount of energy they produce (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004).

The different amount and type of components to be used, affect the possible variable costs both in frequency of occurrence and price. To illustrate the case with an example, the most frequent replacement of parts due to unexpected failure for large turbines is due to gearbox malfunction (Timmer, 2011). Thus gearbox parts as well as added downtime and labor costs, add up to the variable costs. This does not hold for the majority of small turbines since they do not employ gearboxes but direct drive generators.

Another significant factor which differentiates SWT is the inferior wind regimes in which they usually operate along with their considerable smaller swept area and electrical turbine. These factors have a direct effect on the annual energy production which in turn affects the economic analysis of the investment. Small wind turbines require more than twice the time to produce as much energy as the energy spent for their production or have a much higher *Energy payback time* (Figure 24) than large turbines, since energy production is significantly smaller in the urban environment than in open rural areas. Since the energy production can be associated with the cost of energy, as explained in the previous section, it can be deduced that the higher the Energy payback time the smaller the yearly revenues are, rendering the technology less competitive.

Additionally, when the simple payback method is used, it can be misleading regarding the future benefit of the investment. Advocates of SWT claim that contrary to commercial-size wind machines which need to be able to produce bulk power to be competitive to other energy production methods while quickly repaying the initial investment in order to maximize profit, small wind turbines can be considered costeffective as long as they repay for themselves within their lifetime (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004). Also based on the fact that a large number of consumers often buy products of equivalent cost while not expecting any monetary return further strengthens the above statement. Apart from the above, simple payback time calculations lack the possibility of giving any indication on the earnings of a wind turbine for the remaining years of operation after it has repaid for the initial investment. Since wind turbines represent long term investments in many cases substantial profits will occur in the last five years of operation which can repay the investment many times over (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004). Thus when potential buyers calculate the time it will take for the investment to pay for itself but do not take into account the above information or solely rely on the simple payback method, any result above 5 years is ruled out as not interesting.



Figure 24: Energy payback time for small ('Mean Urban') turbine and large ('Mean Open') turbine (Allen, 2008)

Estimations based on the Cost of Energy methods also prove to be of limited use for the case of SWT. The goal of COE models is to provide a comparison of the costs per produced energy for different energy producing methods. Thus they can only reveal to the individual buyer whether the energy system of choice costs more or less than a competing one. Essentially they do not provide with the information needed to assess whether a different type of investment would be more profitable than a wind energy system (such as investing money in a bank).

In the case of Life Cycle methods more variables and assumptions are taken into account which could result in a rather complicated approach for the average user but overall more accurate estimations are provided. Factors such as the interest rate or inflation and their relation to the final result have to be approximated, a fact which can introduce uncertainties on the level of realism of the model's prediction. Nonetheless, researchers indicate that the best overall way to examine the economics of a wind system designed for the built environment is through the construction of a cash flow Table which could present, based on the accuracy of assumed values, a detailed

The final economic difference between SWT and Wind Farms is in the way revenue itself is produced. The acquired revenue of SWT systems is heavily dependent on the fixed, but privileged, utility grid prices which are beyond the investor's control while other renewable energy producers can actively choose the price at which energy will be eventually sold (Simic, 2013). Contrary to government subsidies aimed to benefit farm developers, grants, tax exemptions and other incentives which apply specifically to household RET applications also provide extra profit which needs to be accounted in calculations.

3 Hellenic SWT Market Analysis

In this chapter a review of the SWT energy market status in Greece, along with the according market parameters of influence, will be followed through. A short overview of the Global Small wind turbine market will first take place, presenting valuable information regarding the current status and future growth projections of the industry until 2020, followed by the depiction of the energy status in Greece which will aim to provide insight on whether the niche market established in the country could follow the Global Small wind turbine market trends. Subsequently the current market status regarding this RET field in Greece will be investigated based on the existing wind potential of the country, different possible applications, market stakeholders, products and policies in the way they are shaped by the measures adopted by the country to fulfill its EU obligations while on the effort of overcoming the economic crisis. Finally techno-economic characteristics of the Greek SWT market will be compared to those from other sustainable energy markets which currently are established in the country which represent either fully mature or competing niche markets. The data analyzed in this chapter will lead to the realization of the technological and economic potential of Small wind turbines in Greece.

3.1 Global Small Wind Turbine Market Trend

The global Small wind turbine market has seen steady increase in the past decade with more than 120 new small wind manufacturers having been established between 2000 and 2010 (Figure 25). The market growth is anticipated to continue until 2015 and conservative forecasts predict a growth rate of 20% in the time span of 2015-2020, translating in a cumulative capacity increase of 5GW and an annual capacity increase which will reach an approximated value of 1 GW (Figure 26).

Since 2011 the number of installed small turbines has grown by 11% reaching a cumulative total of at least 730000 installed small wind turbines globally representing more than 576 MW of installed power capacity. At the end of 2011, 74000 new small wind turbines having been erected, accounting for more than 120 MW of installed capacity. This represents a substantial 27% global capacity increase which clearly underlines an increasing interest regarding this technology. China is the currently leading country on SWT implementation with over 500000 installed units, representing 68% of the world market in terms of total as well as new installed units and accounting for 40% of the installed power capacity, while USA and UK follow with approximately 151300 and 11000 installed turbines (World Wind Energy Association, 2013). The US market, accounting for 35% of the installed capacity, has been gradually (since 2007) overrun by the Chinese although it has shown increase in sales since 2008 with 95% of turbines sold in the country being manufactured by US companies (American Wind Energy Association, 2010). The European markets are also significant but still far behind the two leading countries in terms of installed units, despite the substantial research conducted and funded by the European Commission (Wineur, 2007). The rest of the world still lags behind in the implementation of SWT but in developing countries applications aiming to provide autonomy in areas where the national grid is inadequate could become a competitive option.



Figure 25: Last Decade New Manufacturing companies (World Wind Energy Association, 2013)



Figure 26: Market prediction reagarding annual install capacity power increase (World Wind Energy Association, 2013)

Although more than 330 small wind turbine manufacturing companies can be identified in the majority of the developed world, currently five countries account for the 50% of small wind turbine manufacturers: China, USA, Germany, Canada and the UK. The following map presents the distribution of small wind manufacturers worldwide:



Figure 27: Small wind turbine Manufacturers World Distribution (World Wind Energy Association, 2013)

Gradually an increase in the average size of turbines, both in the sense of the rotor swept area and overall rated power production, has been observed, especially in industrialized countries where energy demands are significantly higher and interest has shifted from small standalone to larger-grid connected systems. This size increase also reflects the efforts of the industry to lower the cost of energy by increasing the rated power of the system. The following Figures provided by the European Wind Energy Association's report "Wind Energy The Facts" depicts clearly this trend. Since EWEA argues the universality of the definition of the rated power given by each manufacturer, the according cost per swept rotor area as a function of rated power is presented (European Wind Energy Association, 2009). The same trend can be observed.



Figure 28: Cost of Energy as a function of rated power (European Wind Energy Association, 2009)



Figure 29: Cost per swept rotor area as a function of rated power (European Wind Energy Association, 2009)

Despite the positive global current market feedback and optimistic future predictions, the small wind energy market being highly dependent on local utility prices and RET supporting governmental policies (such as subsidies and tax incentives) which are externally imposed and in most cases impossible to control by the electricity producers themselves, still is characterized as fragile. Since governmental energy policies are a part of a general government planning (along with any International or Union level directives) which is formed based on the priorities of a country, it can be easily understood that the promotion of an underdeveloped market such as the SWT through the adoption of monetary and non-monetary support measures, could be treated as a matter of less importance or even an unnecessary commodity in times of economic crisis.

3.2 Electricity generation regime of Greece

Understanding the current electricity production status of Greece is of importance for the realistic assessment of existing and future SWT implementation opportunities and barriers. The current generation regime directly affects the policies and energy targets of the country and introduces the market framework in which SWT are to operate within.

Greece's electricity system comprises an interconnected mainland grid and non-interconnected islands. The electrical power distribution grid installed on Greek territory is composed of the medium (20kV) and low(400/230V)-voltage lines and distribution installations (refered to as *Network*), as well as the high(150kV)-voltage and extra high(400kV)-voltage lines and transmission installations having been incorporated therein (refered to as *System*). With the exception of the Network of the islands not connected to the mainland's interconnected system, the Network is connected to the System through the high-voltage and medium-voltage substations (Hellenic Republic, 2006).

The Hellenic electricity generation is still heavily dependent on oil, natural gas and lignite regarding its primary sources of energy, making the country one of the most carbon intensive International energy Association and European Union members. In fact, 91% of the *total primary energy supply* (TPES) has been covered by fossil fuel (International Energy Agency, 2012). Other forms of energy include hydropower, biofuel, wind, solar, geothermal and ambient heat used in heat pumps but, as it can be also observed from

Figure 30, still account for a small fraction of TPES (2011 Data). Electricity generation generally follows the same trend being primarily dependent on fossil fuel, with a major difference being observed on the type of the primary fuel itself. Nonetheless hydropower generation and RET have a substantial share on electricity generation and are constantly gaining ground over conventional sources. Figure 31 depicts the Electricity production market shares across fuel and net electricity imports referring to the interconnected system (Appendix).



Figure 30: Energy consumption by source in million tons of oil equivalent (Mtoe) (International Energy Agency, 2011)



Figure 31: Annual shares of fuels and net imports for Greece in June 2013 (Hellenic Electricity Market Operator S.A, 2013)

Oil has been the dominant energy source since 1973, with the entire supply per year being rather stable for the last decades, accounting for 53-58% of the total primary energy supply. Nonetheless electricity generation consumes less than 0.30% of oil supplies in the interconnected electrical system (Invest in Greece

Agency, 2008) while 90% percentage is consumed in few non-interconnected islands, making oil overall, the least used fuel regarding electricity production.

Coal is the second largest energy source of the country with a supply accounting for more than 27%of TPES in 2010 with an estimated annual primary production of 87283.15 MWh of energy (Ministry of Environment Energy and Climate Change, 2011), accounting for more than 78% of primary energy production in 2010. Since Greece possesses large lignite reserves (Greece is currently the second largest lignite producer in Europe and the sixth largest in the world (International Energy Agency, 2011)), coal is being produced domestically by 97% while few imports originate from Russia. The vast majority of extracted coal (98% in 2009) provides the main fuel for feeding conventional power production plants for the production of electricity and thus for the past decade, lignite has accounted for more than half of total Greek electricity production (RAE, 2013). Nonetheless the country, conforming with EU directives, has been gradually reducing lignite use for electricity production in order to promote RET and to decrease the substantial Greenhouse gas emissions. This is evident from the drop of electricity production participation from 53,15% in late 2011 (Regulatory Authority for Energy (RAE), 2012) to 46% in June 2013. Natural gas accounted for 12% of TPES in Greece in 2010 with a high electricity-production-driven demand growth during the last decade. Demand is expected to double from 2009 to 2019, gradually increasing natural gas market share as compared to other fossil fuel sources and future predictions by the national regulator of Greece (DESFA) estimate electricity generation to account for 68% of total demand in 2015 and for 61% in 2020 (International Energy Agency, 2011). The fuel is imported from Russia, Algeria and Turkey and several major pipelines, such as the Southstream and ITGI interconnecting pipelines are under construction in order to expand the grid and enable exports to other European countries (Invest in Greece Agency, 2008).

The Hellenic RES (excluding Hydro power) electricity generation market share is growing fast and the country has set high targets for the near future since Renewable Energy resources are abundant and can provide opportunities for economic growth. Nonetheless due to very low cost for conventional electricity production due to indigenous resources (lignite) RET have not achieved grid parity generation of electricity at a levelized cost which is less or equal to the price of purchasing power from the electricity grid (Wikipedia, 2013) and directly reflects the price of electricity originating from RES necessary to compete unrefined fossil fuel electricity (SchalkCloete, 2013). RES in Greece currently operate under a guaranteed Feed-in Tariff system while renewable energy plants generating electricity, with the exception of large hydro plants, are not integrated in the wholesale electricity market (Ministry of Environment, Energy & Climate Change, 2010). The country has reached its 1^{st} interim target of 9,1% share of renewable energy in the final energy consumption (set by the EU Directive 2009/28/EC) by achieving a corresponding percentage of 9.7% in 2010 (European Commission, 2013). Also in 2010 RES accounted for 7.5% of TPES and in the time span between 2011 and June 2013 the electricity generation for which RES accounted for, grew from 5% to 15,16% (Regulatory Authority for Energy (RAE), 2012; Hellenic Electricity Market Operator S.A., 2013). In the smaller scale, domestic PV implementation is growing fast and is dominating the market. Nonetheless since PV have reached their goal regarding installed capacity in the country and are currently producing a surplus they are steadily receiving diminishing support, in the sense of guaranteed prices gradually becoming reduced, in an effort of the government to promote further other RES and mainly Wind Energy. This trend has been also noticed in the EU in total (European Commission, 2013). In this sense SWT could be benefited substantially and gradually acquire a large part of the small scale domestic electrical generation market.

SWT, although present in Greece, are not yet considered in Figures 32 and 33 due to very low production or due to use in non-grid connected applications. Despite this fact, the significant wind potential of the country (described in the next sectors) could provide a place for SWT in the total electricity generation in the direct future and a similar trend to the growth of Roof PV could be noticed for the analogous case of "Roof" turbines. Adoption of this form of RET and the establishment of a mature market would further increase electro generation from renewable sources and would help the country reach its future EU (18 % RET participation on the total electricity) goals.



Figure 32: Monthly Installed RES Capacity in Greece Interconnected System (Hellenic Electricity Market Operator S.A., 2013)



Figure 33: Total Monthly Greek Electricity Generation From RES and Cogeneration Units (Hellenic Electricity Market Operator S.A., 2013)

RES have increased their share in electricity production in the islands from 18,5% in the first seven months of 2012 to 23,8% in 2013 with a number of islands achieving shares of over 20% (Crete-31,8%, Siros-34,5%, Milos-25,4%, Paros/Naxos/Ios-23,8%, Lesvos-21,4%,) (Michanikos-online, 2013).

3.3 Institutions - Organizations

The main institutions involved in production, transmission, distribution, pricing and policy setting regarding Renewable energy in Greece as well as stakeholders responsible for the implementation and promotion of RES and especially Small Wind Turbines (apart from involved companies which are described separately on a following chapter) are presented in the following paragraphs. A description as well as a map which will help the reader understand the manner which these organizations are interconnected, is provided during this sub-chapter.

In short the following Institutions/Organizations are identified:

- Ministry of Environment, Energy and Climate Change (MEECC)
- Regulatory Authority for Energy (RAE)
- Hellenic Transmission System Operator (DESMIE S.A)
- Independent Power Transmission Operator (IPTO or ADMIE) S.A.
- Hellenic Electricity Distribution Network Operator (HEDNO) S.A.
- Hellenic Electricity Market Operator (LAGIE) S.A
- Centre for Renewable Energy Sources and Saving (CRES)
- Public Power Corporation (PPC) S.A
- Hellenic Wind Energy Association (HWEA)
- Regional Administration Units

The *Ministry of Environment, Energy and Climate Change (MEECC)* was formed in autumn 2009 and is the central institution responsible for the transposition of energy related EU directives into Greek legislation and Energy Policy making in Greece (Ministry of Environment, Energy & Climate Change, 2010)). MEECC has replaced the Ministry of Environment, Physical Planning & Public Works and the Ministry of Development, that were formerly in charge of environmental and energy affairs respectively, but often promoted contradictory policies.

The *Regulatory Authority for Energy (RAE)* was set up in 2000 as the independent regulator for all energy markets as defined by the provisions of its founding legislation, L2773/1999. RAE acts independently to safeguard, supervise and monitor the operation of all sectors of the energy market and is obligated to investigate the clarity of procedures regarding the issuance of licenses. With the transposition of the EU third internal energy market directives in August 2011, RAE is now also responsible for licensing, secondary legislation and market control and supervision (International Energy Agency, 2011). Finally RAE acts as a dispute settlement authority with respect to complaints against transmission or distribution system operators in both electricity and natural gas sectors (Ministry of Environment, Energy & Climate Change, 2010). The Hellenic Transmission System Operator (DESMIE) S.A was founded in 2000 by Law 2773/1999 of which objective was to operate, ensure the maintenance and the development of the Electricity Transmission System across the country (formerly controlled solely from PPC), as well as its interconnections with neighboring grids, to ensure the country's supply of electricity in a sufficient, safe, cost effective and reliable manner (Hellenic Transmission System Operator S.A, 2013). Also HTSO was obligated to grant access to all licensed or licensed exempted producers to the utility grid. HTSO's obligations have been undertaken by the Hellenic Electricity Market Operator (LAGIE S.A) and the Independent Power Transmission Operator (IPTO or ADMIE S.A) since February 2012 (Econews, 2012). Both companies were established in compliance with Law 4001/2011 and European Union Directive 2009/72/EC regarding the adoption of common rules in the organization of EU electricity markets.

The Independent Power Transmission Operator (IPTO or ADMIE) S.A was created in 2012 by Law 4001/2011, in order for the Hellenic legislation to be harmonized with the EU Directive 2009/72/EC. ADMIE undertook the role of the Transmission System Operator for the Hellenic Electricity Transmission System (SYSTEM), and currently is responsible for the System's, operation, maintenance and development as well as the safe, efficient and reliable energy supply across the country and cooperation with other Operators (Independent Power Transmission Operator (IPTO or ADMIE) S.A., 2013).

The Hellenic Electricity Distribution Network Operator (HEDNO) S.A was also formed in 2012 by Law 4001/2011, in order for the Hellenic legislation to be harmonized with the EU Directive 2009/72/EC. The role of HEDNO is the operation, maintenance and development of the power distribution Network (NETWORK) in Greece. Administrative branch of HEDNO is the Operator for the Non-Interconnected Islands (ONII or DDN). Regarding the connection of SWT of the country, HEDNO is responsible for the connection to medium/low voltage lines, absorption of energy from operation of Licensed or exempted from License producers which have successfully issued a Power Purchase Agreement (PPA).

The Hellenic Electricity Market Operator (LAGIE) S.A was created based on Law 4001/2011 and currently carries out the activities of the former Transmission System Operator (DESMIE S.A) except from the ones defined by Article 99 of Law 4001/2011, which have been undertaken by IPTO S.A. Essentially the Market Operator applies the rules governing the operation of the Electricity Market in accordance with the provisions of Law 4001/2011 and delegated acts thereunder and in particular the Daily energy planning where the System Marginal Price for which electricity was eventually sold, is calculated (Hellenic Transmission System Operator S.A, 2013). Essentially LAGIE deals with the financial aspects of the Hellenic Energy Market and is responsible for the purchase of RES produced energy at specific prices (FIT), by the according Operator. In order to promote renewable energy in the country a special *RES Account* managed by LAGIE has been issued which is funded by a levy paid by consumers to finance according incentives (expressed as FIT) (Directorate-General for Economic and Financial Affairs, 2013).

The *Centre for Renewable Energy Sources and Saving (CRES)* is the national body responsible for promoting renewable energy sources and the rational use of energy and energy saving. It is supervised by the Ministry of Environment, Energy and Climate Change and has financial and administrative independence (International Energy Agency, 2011). CRES facilitates national energy planning, assists in the formulation of energy policy and fosters research and development related to renewable energy. As part of

the Research and Technology's role, CRES is the link between basic research and industry, aiming to develop domestic technological products and services.

The *Public Power Corporation (PPC) S.A* was historically the first and only, till 1999, energy company in Greece. Currently PPC S.A remains the country's biggest power producer and electricity supply company, holding assets in lignite mines, power generation, transmission and distribution (PPC S.A, 2013). PPC was the former owner and operator of the Transmission System and Distribution Network and still retains the ownership of the latter. Via its subsidiary PPC Renewables S.A PPC has the possibility to undertake large scale RES projects.

The *Hellenic Wind Energy Association (HWEA)* is the main nongovernmental organization regarding the positive promotion of Wind Energy in Greece. Founded in 1991 and renamed in 2005 as Greek Scientific Union for Wind Energy, HWEA's efforts are focused on providing detailed and accurate scientific arguments regarding required reforms in the country for the development of the Wind energy technologies related investment environment (Hellenic Wind Energy Association, 2000).

Regional administration units (municipal, prefecture and regional level) play an important role in approving specific aspects of licensing such as those regarding environmental and land use concerns. In Greece such units can either create barriers regarding the implementation of RES units or create opportunities for community-based exploitation of RES. This fact holds dearly for SWT, as it will be explained further on this thesis.



Figure 34: Organization Map

3.4 RES Policy in Greece – SWT related Targets and Measures Overview

Greece is a Member state of the European Union and as such is set to meet its Kyoto Protocol and 2020 EU targets by harmonizing its RES policies to the according EU Directive 2009/28/EC. In recent years, renewable energy production methods have become more prominent on the political agenda and the country has made substantial effort to reform its energy policies by the adoption of mainly Regulatory, Financial and Technical measures, such as the rearrangement of Ministries (most importantly with the

formation of the *Ministry for Environment, Energy and Climate Change*) and existing legislative framework (analyzed in the next subchapter) and the issuance of a Feed-in-tariff scheme. Unfortunately as off yet, Greece has not issued specific targets and measures for the adoption of SWT but instead has adopted a broad variety of policy measures which directly or indirectly affect this technology. As such, this subchapter will present a review of these Small wind turbine implementation influencing measures.

Greece has formed a National Renewable Energy Action Plan to provide for specific measures needed to meet the 2020 targets and to determine the contribution and required future installed capacity of different RET on possible scenarios for the development of the energy sector until 2030, by taking into account parameters such as cost-effectiveness, domestic value added, security of energy supply, socioeconomic and demographic factors as well as identified and future barriers (Ministry of Environment, Energy & Climate Change, 2010). The RES policy for the consumption of energy originating from renewable sources until the end of 2020 is mainly expressed by four national targets which have been stipulated in accordance with EU Directive 2009/28/EC, (EEL, 140/2009) which established a European framework for the promotion of renewable energy, setting mandatory national renewable energy targets for achieving a 20% share of renewable energy in the final energy consumption and a 10% share of energy from renewable sources in transport by 2020 (European Commission, 2013). These targets, as incorporated and described in Article 1 of Law 3851/2010, have also become the guiding principle of RES legislation in the country (Watson, Farley & Williams, 2012).

These targets are (Hellenic Republic, 2010):

- 1. RES produced energy must contribute to the gross final energy consumption to a share of 20%
- 2. RES produced Electrical Energy must contribute to the gross electrical energy consumption to a share of at least 40%
- 3. RES produced energy must contribute to the gross final energy consumption for heating and cooling to a share at least 20%
- 4. RES produced Electrical Energy must contribute to the gross electrical energy consumption for transportation to a share of at least 40%

It is worth noticing that the National goal for the contribution of RES produced energy to the gross final consumption (20%) is 2% higher than its EU obligation (18%) and almost triple to the 6,9% share in 2005. Nonetheless Greece is showing a steady progress in meeting these goals since the 2010 RES share increased to 9,7% and the interim target (calculated as the average of 2011/2012 share) was surpassed by 1% to 2%, reaching a share of 9,1% (European Commission, 2013). A detailed Table regarding the progress of all EU Member Stated can be found in the Appendix.

According to the National Renewable Energy Action Plan the proportional installed capacity for 2010-2020 per RET in order to successfully reach the set electrical energy consumption targets is presented in Figure 35. These projections are based on economic forecasts agreed for the *Stability, Development and Reconstruction Program* (Greek Recovery Plan), when after an initial period of stabilization, the economy is expected to grow with moderate rates peaking at about 2.7% in 2015 and remaining at that level with a slight increase to 2.9 by 2020 and a slight decrease later on towards 2030 (Ministry of Environment Energy and Climate Change, 2011).



Figure 35: Estimated required installed capacity from the different RET to 2020 (Ministry of Environment, Energy & Climate Change, 2010)

As indicated by the reference scenario, almost 7,5GW of power originating from Wind energy units (thus including Small Wind Turbines) are foreseen the above targets are to be met. More specifically the RES installed capacity of Wind Energy is expected to be equal to 3,78 GW by 2015, representing 53,0154% of the total RES installed capacity and 6,25 GW by 2020, representing 63,0676% of the total RES installed capacity. The National Renewable Energy Action Plan has also set priorities regarding the upgrading of the Interconnected and Non-Interconnected System in order to promote the use of Wind energy. Measures that are planned for the electricity production in the interconnected system will be based on power production from Large, medium and small scale plants as well as applications for electricity generation in the residential and tertiary sector buildings (Ministry of Environment, Energy & Climate Change, 2010). The main priority for the non-interconnected Network is their gradual interconnection to the mainland grid in order for future local production units to supply excess electricity to the Network or System and to substitute existing fossil fuel operating plants. Also for islands whose connection is deemed difficult or not cost effective, autonomous systems are to be promoted thus providing an opportunity for the deployment of SWT systems. Clearly these data and facts indicate a favorable and promoting policy strategy regarding the implementation and future development of Wind energy in Greece but unfortunately the lack of distinction between large and small turbines is evident. Thus only an estimation, that SWT (with the according promoting measures) could follow this projected increase in installed capacity, is applicable. In any case, the implementation of small wind turbines is in accordance with the Plan and could provide economically and technologically feasible solutions.

An overview of other existing government policies and adopted measures for the promotion of RET which have an impact on Small wind turbine implementation, is given on Table 7. As it can be identified from the Table, Greek governments have proceeded in mainly regulatory changes while financial measures, apart from the establishment of a Feed-in Tariff system with distinct prices per RET, lack in numbers. Since it goes beyond the scope of this Thesis, the manner in which these measures affect SWT deployment is not to be further elaborated upon. Nonetheless these measures have set the ground rules for the establishment, operation, development and acceleration of RET deployment to which Small wind turbines application effectively abide by.

Table 7: Government issued Policies and Measures to promote RES (SWT relevant) (Ministry of Environment, Energy & Climate Change, 2010)

Name and reference of the Measure	Type of Measure	Existing, completed or planned
L.2244/94 "Regulation of power generation issues from renewable energy sources and conventional fuels and other provisions"	Regulatory	Existing
L.2773/99 "Liberalisation of the Electricity Market-Regulation of energy policy issues and other provisions"	Regulatory	Existing
L.3468/06 "Generation of electricity from renewable energy sources and through high-efficiency co- generation of electricity and heat and miscellaneous provisions"	Regulatory	Existing
L.3851/2010 "Accelerating the development of Renewable Energy Sources to deal with climate change and other regulations in topics under the authority of MEECC"	Regulatory	Existing
Feed-in-tariff scheme per kWh of electricity produced by RES (Laws.2244/1994, 3468/2006, 3851/2010)	Financial	Existing
Development Law 1892/90, 2601/1998 and 3299/2004 (amended by the L.3522/06 and ministerial decree, Gazette B' $1292/25.07.2007$)	 Subsidy for the initial cost of the investment plan Subsidy for leasing Tax deduction 	Completed

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Mandatory deadlines for RES licensing procedure $(L3734/09 \& L.3851/10)$	Regulatory	Existing
Coverage of total primary energy consumption with energy providing systems based on RES, CHP, district heating on a large area scale/block scale as well as heat-pumps for all new buildings by 31.12.2019 and for all new public buildings by 31.12.2014 (L.3851/2010)	Regulatory	Existing
2008 national campaign for the promotion of RES (guidebooks for assessment, evaluation, environmental impact and installation procedure for all different RES technologies)	Information Campaign	Existing
Tax deduction scheme, set by $L.2364/95$ and $L.3522/2006$, that considers all small domestic RES systems to be eligible for a 20% tax deduction capped at \in 700 per system.	Financial	Existing
Application and reinforcement of the National Transmission Development Plan (NTDP), elaborated by the System Operator: a) Upgrading of grid interconnections in the mainland, b) Interconnection of the non-interconnected islands according to strategic planning elaborated by the System Operator	Technical	Existing
NSRF National Strategic Reference Framework - 4th Framework Programme: e.g. a) "Exoikonomo" Program for energy efficiency in Local Authority organizations, b) Exoikonomo kat'oikon" Programme, c) Action "Green Tourism, d) Action "Green Enterprise"	1. Financial 2. Actions for developing and promoting RES installations	Existing
Measures for the building energy consumption reduction in the public sector $(L.3855/2010)$	Regulatory	Existing/Planned
Guidelines and directions for the licensing of RES-E based on the energy mix included in the NREAP	Regulatory	Planned
Further development of the distribution grid based on the smart grids principles	Technical	Planned

3.5 Small Wind Turbine Legislation

The legislative framework which defines the operating and economic parameters regarding the use of Small Turbines in Greece is expressed mainly by four laws and several amendments and supplementary ministerial decisions. These laws are Law 2773/1999, Law 3468/2006 as amended by Law 3851/2010 and Law 4001/2011 and supplemented by several ministerial decisions including the Permit Regulation for Renewable Energy Sources (Ministerial Decision $\Upsilon A \Pi E / \Phi 1 / 14810 / 04.10.2011$) (Tsirakopoulou, 2011). This chapter will describe the key aspects of Laws 2773/1999 3468/2006 and 3851/2010 in order to present the current legal characteristics of the Hellenic RET energy generation regime in which this particular technology will struggle to be established. This analysis will be of critical importance for the later realization of legal barriers regarding this technology in Greece. The signed Memorandums of Understanding on Specific Economic Policy Conditionality between the Hellenic Government and European Commission, the ECB and the IMF are not included in this analysis since they represent obligations of the country which in order to take place must be included in existing legislative framework by the composition of new Hellenic laws. The suggestions of the First and second Memorandum regarding the Energy sector in Greece are described in the legal barrier sub-chapter of Chapter 4. It is most important also to notice that these legal documents accepted by the Hellenic Parliament do not include specific terms or conditions for the realization of SWT in Greece apart from urging the country to harmonize with EU Directives.

The main legislative act regulating the liberization of the Hellenic Energy market is Law 2773/1999 "Liberisation of the electricity market - Regulation of energy policy issues", under which the Energy market, previously fully controlled by the state owned Public Power Corporation (PPC), became available for independent power producers (IPPs). The particular law essentially transposed the relevant EU Legislation into domestic law and set out the framework for the licensing of power generation facilities in Greece from IPPs. In order for the generation, transmission, distribution and sale of electrical energy from producers to be lawful, relevant licenses must be provided. The licensing process can be divided into three main phases which include the issuance of the Operation, Electricity Generation and Installation and Environmental license respectively (Kyriakides Georgopoulos & Daniolos Issaias Law Firm, 2011). In Article 35 of Law 2773/1999, the regulations regarding the production of electric energy from RET were first described. More specifically it is stated that for generation units of less than 50 MW installed capacity (such as SWT), the system operator must provide priority for the use of their produced energy. Also any smaller than 20kW electricity producing station was granted exemption from the licensing procedure, thus accelerating the completion of such projects. Despite the changes regarding the Electricity Market in Greece introduced by Law 2773/1999, a specific legislative framework regarding RET, and in particular low power producing technologies such as SWT, was not introduced and no other benefits were provided. The Law was deemed insufficient, a fact which led to the introduction of a number of modifications.

The law that radically changed the landscape of the market for renewable electricity was Law 3468/2006 "Generation of Electricity using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions". The purpose of this law was to harmonize effectively the Greek legislation with Directive 2001/77/EC of the European Parliament and Council of September 27, 2001, on the promotion of electricity produced from renewable energy sources in the internal electricity market (OJ L 283/27.10.2001) and, on the other hand, the promotion, by granting priority to the

generation, of electrical power from Renewable Energy Sources (RES) and high-efficiency co-generation of electricity and heat plants in the internal electricity market, on the basis of rules and principles. With this law strong incentives for investors to exploit renewable energy sources were finally provided. Following the licensing procedures established by previous laws, in order for a producer to be granted permission for generation, installation of production unit and connection to the Network for the selling of electrical power the according licenses must be issued. The *Electricity Generation License* in order to be issued required the permission of RAE and the according ministry and was granted for a period of up to twenty five (25) years which could be renewed for up to an equal time. In contrast to previous laws, 3468/2006 specified exemptions from the Electricity Generation License for each RET. Specifically regarding Wind Energy, Article 4 (paragraph 1, section d) exempted generation units with an installed capacity less than, or equal to 20 kW if they were located in isolated micro grids (as they are defined in article 2 of Law 2773/1999), units with an installed capacity less, than or equal to forty (40) kW if they were located in islands which are not connected to the mainland's interconnected System and units with an installed capacity of less than, or equal to fifty (50) kW if they were located in the Interconnected System (Hellenic Republic, 2006). Also with respect to autonomous RET stations with an installed capacity up to fifty (50) kW no attestative act of RAE was required. Regarding the *Installation* and *Operation* licenses, the law stated that in the case of Wind Energy units exempted from the issuance of the Electricity Generation license, no further license would be required. Nonetheless the approval of environmental terms with respect to the installation of power generations plants using RES would be still mandatory and if granted would be valid for ten (10) years with a possibility for extension for one or more times and up to the same time-period at each time. These changes with respect to previous laws established a favorable time frame regarding small wind turbine investments. The most important aspect of Law 3468/2006 was the establishment of a guaranteed pricing system (*Feed-in tariffs*) which ensured different prices per location and generation technology in Greece. This electricity *Market-Independent* FIT policy essentially ensures a guaranteed minimum payment based on development costs of the particular technology most commonly accompanied by a purchase guarantee (Couture & Gagnon, 2010). By obligating the Hellenic Operator of the System to conclude an electricity sale contract with the holder of the relevant production authorizations, the government guaranteed the selling of RET produced electricity. Furthermore, as stated in Article 13 of Law 3468/2006, the power generated by RET units was to be priced, on a monthly basis, according to Table 8 (Wind Energy Data only included). Essentially by this Article wind turbines where for the first time in Hellenic history treated separately from RET and granted special treatment in order to be promoted. Nonetheless a differentiation between small and large wind turbines was still to be established in terms of pricing a fact which hindered the economic potential of SWT at the time.

	Price of Energy (Euro/MWh)		
Generation of Electricity from	Interconnected System	Non-interconnected islands	
Wind Energy	73	84,6	
Offshore Wind Energy		90	

Table 8: (Wind) Energy prices as stated in Law 3468/2006 (Hellenic Republic, 2006)

In order to control the origin of electricity produced in legally operating facilities using RES, the producers were obligated to issue *Guarantees of Origin* which specified the source of the power generated and stated the generation date and the location. The authorities in charge of issuing the Guarantees of Origin of Electricity were the System Operator, the Network Operator of the islands not connected to the interconnected System while RAE was appointed the authority in charge of overseeing the Guarantee of Origin procedure (Hellenic Republic, 2006).

Although Law 3468/2006 set the regulations regarding RET energy production which boosted the RET market and increased substantially the penetration of renewable energy in the total energy consumption of the country, after four years amendments were required in order for Greece to reach its national targets for the RES until the end of 2020, based on EU Directive 2009/28/EC (EEL, 140/2009) and further control and accelerate the licensing procedures due to a large number of pending license authorizations. Eventually Law 3648/2006 was subject to significant amendments, mainly by (the currently in use) Law 3851/2010 on "Accelerating the development of Renewable Energy Sources to deal with climate change and other regulations addressing issues under the authority of the Ministry of Environment, Energy and Climate Change".

In an effort to simplify the licensing procedure regarding small energy producing units, Law 3851/2010 has exempted from the issuance of Electricity Generation, Installation and Operation license a number of RET. Regarding wind energy, all stations with installed capacity of less or equal to 100 kW do not require such authorization which also means that they do not need to fulfill criteria for the issuance of such licenses. Practically this facilitates potential investors since they are not obligated to present specific data, such as wind velocity measurements from an IEC-17025 certified body. Also Law 3851/2010 states that no Preliminary Environmental Valuation and Assessment (scoping study) is required for the stations producing electrical energy from Renewable Energy Sources, accompanying projects required for the electrical connection to the System or the Network, on-site road works or the site access road works. Nonetheless small wind turbine installations are obligated to abide by the process of Environmental licensing and thus investors are required to issue an Approval of Environmental Conditions (AEC) decision. This holds especially in the case of fields located within demarcated areas of the Natura 2000 network, in coastal zones at a distance shorter than one hundred (100) meters from the waterline of the shore (apart from uninhabited small islands) and in less than one hundred and fifty (150) meters neighboring fields which have issued a production license, AEC decision or a Connection Offer of a R.E.S. station of the same technology and the total capacity of the stations exceeds the above specified limit. Exempted are turbines installed on buildings, other built structures or inside organized receptacles of industrial activities (Hellenic Wind Energy Association, 2012). Also exempted from the issuance of AEC are wind powered stations producing electricity installed in field courts, as long as their installed electrical capacity does not exceed 20 kW (Hellenic Republic, 2010). Since the majority of SWT are installed in the previously mentioned cases, and equal to or less than 20kW power output turbines are usually preferred by investors, it can be concluded that the AEC decision is seldomly required.

Although the licensing procedure has been greatly simplified, investors are obligated to issue a Grid Connection request to the according operator (PPC S.A) and subsequently request for selling to the grid to the according operators' the Hellenic Market Operator S.A and Independent Power Transmission Operator S.A regarding the interconnected network or PPC S.A for the non-interconnected network. If the operator accepts the Grid connection request, then the producer must issue a guarantee fund which must be provided to the operator in case connection to the System of Network is not completed during a specific time period. Regarding SWT installed in buildings this guarantee fund is not required (Hellenic Wind Energy Association, 2012).

To further promote small wind turbines the guaranteed pricing system (*Feed-in tariffs*) introduced by Law 3468/2006 underwent radical change. With the current pricing system, small turbines receive different and highly favorable prices as compared to large turbines. The prices of SWT produced energy are presented in Table 9. For reasons of comparison the according large turbine prices are included as well:

	Price of Energy (Euro/MWh)		
Generation of Electricity from	Interconnected System	Non- interconnected islands	
Wind energy exploited through land facilities with capacity greater than 50 kW $$	87,85	99,45	
Wind energy exploited through facilities with capacity smaller than or equal to 50 kW	250)	

Table 9: (Wind) Energy prices as stated in Law 3851/2010 (Hellenic Republic, 2010)

As it can be identified, an increase of 242,45% and 195,5% with regard to the previous prices for interconnected and non-interconnected systems holds for smaller than 50 kW wind turbines. Also no differentiation regarding the On or Off grid application holds. An additional rise in prices is specified regarding production from wind energy stations located in places of low wind velocity in Locations of Wind Suitability (LWS). As stated in Law 3851/2010 the additional increase must be inversely proportional to the wind capacity of the locations expressed in equivalent operating hours as they are ascertained based on the actual electrical energy produced and accounting for the production efficiency of the wind turbines being used. Also at the end of every calendar year, the authorized Operator is obligated to provide additional remuneration to wind energy producers, regardless of installed capacity to compensate for energy cuts (Hellenic Republic, 2010).

Law 3851/2010 does not cover important issues such as noise emissions or land/urban planning legal restrictions. By searching the general urban planning legislation for such matters, joint ministerial decision

13727/724/24.7.2003 stated in Official Gazette B' 1087/5.8.2003, as amended by joint ministerial decisions 19500/4.11.2004 stated in Official Gazette B' 1671/11.11.2004 and $3137/191/\Phi.15$ stated in Official Gazette B' 1048/4.4.2012 categorizes electrical energy production systems depending on their noise emission. Table 10 presents this categorization:

Table 10: Categorization of noise emission levels per rated power (Hellenic Wind Energy Association, 2012;
Hellenic Republic, 2102)

Rated Power kW	≤20	>20 ≤700	>700
Noise emission Level	-	Low	Medium

Also with regard to the same ministerial decision, small wind turbines of rated power under 20kW have no location installation limitation except from installations in traditional settlements, city parts of historic value and RAMSAR areas. Larger turbines are not permitted inside Urban area borders (Hellenic Wind Energy Association, 2012).

Following the description of the current legislative framework regarding small wind turbines in Greece, it is evident that a complicated yet sufficient legal system which highly promotes the use of SWT has been established in the country since 2010. Despite the fact that the licensing procedure has been described in detail and over 958 licenses and connection to the grid requests have been filed to according operators, the Ministry of Environment, Energy and Climate Change proclaimed in 03/12/12 and 16/04/2013 a public consultation for a new Legal Act, under the name of "Regulation of Renewable Energy Sources (RES) matters and other provisions". A direct consequence of the introduction of a (yet not in force) new Law was the suspension of any licensing procedures thus suspending the installation and connection of new small wind turbines. The reasons and further details on the matter will be addressed in the according Legal Barrier chapter.

3.6 Market Status

3.6.1 Hellenic Wind Potential-Mainland and Islands

As described in the technological description of SWT and wind energy in general, the foremost important factor for the production of electricity from wind is the steady and sufficient, both in velocity magnitude and frequency, presence of the wind itself. Also all described economic models for assessing the cost effectiveness of an investment are linked to the wind potential which essentially defines the potential annual energy production. Hence where the wind regime is adequate and reliable and constant operation can be guaranteed, the investigation for SWT implementation can be assumed to be worthy. Furthermore it should be noticed that small wind turbines are best suited for operation in areas with medium to high Wind potential or in areas where wind velocities range between 6m/s to 9 m/s (Georgakopoulos T., 2011).

Greece is divided in the Balkan Peninsula mainland and the over 2000 islands covering more than one fifth of the country's territory. The Greek coastline is 13780 kilometers long (European Commission, 2009) while both a large part of the mainland and majority of islands are mountainous. The largest urban centers of Greece are identified in Athens (Southern Mainland), in Thessaloniki (Northern Mainland) and Heraklion (Island of Crete) while numerous smaller cities are equally spread across the mainland and more scarcely distributed in the islands. From the above facts, it can be derived that the country has significant geographical advantages regarding the implementation of SWT, which affect the anemological characteristics as well, further to be analyzed in the next paragraphs.

The wind potential map of Greece is shown in Figure 36 below. As it can be identified most of the coastal regions of mainland Greece have average yearly wind speeds between 4-6 m/sec. Since coastal areas have a low terrain roughness, the wind profile increases smoothly with height, making them adequate for small wind turbines with low cut in wind speeds. Wind speeds further increase in the mountainous areas of Northern, Northwestern, and Central Greece as well in the Southern Peloponnese reaching velocities of over 6m /s and up to 9 m/s. The morphology of the Greek mainland creates regions which accelerate wind masses enabling them to reach high average velocities but high terrain roughness (forest areas) does not allow for smooth velocity profiles and introduce turbulence. Nonetheless implementation of SWT at the urban centers of these regions could provide a feasible possibility for local electricity micro-generation to be sold to the general utility grid. The high winds of mainland Greece are only surpassed by the wind regime of the islands which retain year round average wind speeds from 7 m/s to 10 m/s throughout their region. Both islands located at the Western Ionia Sea and foremost smaller island complexes located in the Aegean Sea provide large potential for implementation of wind energy technologies. Most islands remain noninterconnected to the main grid and are heavily dependent on fossil fuel (oil) factories, a current situation which could be drastically altered if they are connected to the main grid and existing wind potential is exploited both on a large and small scale. In many areas average winds also surpass 10 m/sec making them extremely interesting for SWT which would be designed to withstand high aerodynamic loads. In islands where interconnection to the grid is difficult or not worthy due to their distance to the mainland and thus large scale wind energy implementation is not an option to be considered, SWT can provide the means to effectively harvest the abundant wind energy and establish autonomy or reduction of fossil fuel

use. Regarding the two largest and most inhabited islands of Greece, Crete (South) and Euboea (Center), large wind potentials are identified locally but especially in the case of Euboea are significant in magnitude. An additional advantage of Euboea is its interconnection to the mainland grid which grants the existing wind potential as highly and easily exploitable.

The determination of the average yearly wind speed magnitudes presented in this chapter has indicated that yearly energy production could be assumed to be substantial for the implementation of SWT. Although this analysis does not regard the frequency of occurring wind speed velocities or other detailed meteorological data, it presents facts which can lead to the assumption that Greece has a favorable wind regime, especially in the area of islands and mountainous Northern inhabited regions. As such the technological potential of small wind turbines in Greece can be regarded as high.



Figure 36: Average Wind Speeds in Greece (Invest in Greece Agency, 2008)

3.6.2 Potential SWT Applications

As indicated by previous chapters, SWT are most commonly utilized for the acquisition of a direct or indirect income by the selling of produced electricity to the interconnected or non-interconnected grid (Ongrid applications) or for the establishment of autonomy in the form of produced and subsequently stored energy (Off-grid applications). Although the use of SWT in the above manners is usually solely related to household-installed systems, this is not necessarily the case: numerous other possible applications exist beyond household implementation. This chapter will give further insight regarding all possible applications of SWT in the Hellenic region.
It is evident that the most cost-efficient application regarding the implementation of SWT in the Hellenic mainland's urban centers includes the selling of produced electricity directly to the Network grid at a guaranteed price. As explained in previous chapters, RET in Greece are subsidized since they have not still achieved grid parity and cannot directly compete with conventional energy sources. Thus, guaranteed government-set prices for renewables can provide profit for the household user (Hellenic SWT guaranteed prices are discussed on the later chapters). Nonetheless apart from residences other urban buildings and structures can house SWT and benefit in analogous ways.

Depending on the scale of the small wind turbine to be used, available roof or ground space and wind potential in the area, virtually any non-residential building can utilize SWT for electricity production. In this sense the following buildings existing in the urban or near urban environment can be identified (European Wind Energy Association, 2009):

- Industrial
- Governmental
- Schools and Universities
- Public Centers
- Athletic Stadiums
- Airports
- Car Parking Areas, Marinas- Docks

More analytically industrial buildings can benefit from the use of SWT aiming at the reduction of electricity bills and possible taxation benefits. Since these buildings often possess substantial roof areas or in general have increased heights they can increase their energy yields by implementing multiple rows of turbines. Government, University and school buildings, Public centers can utilize SWT in the same manner but also can contribute significantly in raising public awareness regarding this particular RET. Athletic Stadiums, due to often unique architectural rooftop characteristics, could also house small turbines which would require less foundation area in comparison to other competing RET (Photovoltaics).

An interesting opportunity for SWT implementation can be presented in airports, especially located in the outskirts of urban centers. Since the dominant RET of "roof" Photovoltaics cannot be installed due to possibly hazardous reflection issues, small wind turbines could be installed over hangars and in other open unobstructed areas. Since Greece considers tourism to be its most profitable industry with millions of annual visitors, it can highly benefit by projecting a "Green" profile which could further boost the branch and create a positive public attitude towards the country's efforts to adopt RET.

Apart from the above utilizations, small wind turbines can be used for On-grid lighting applications (European Wind Energy Association, 2009) in car parking areas, city garage buildings, marinas and docks or innovative Street Lamp concepts, with generated power feeding exterior lights and daytime or surplus production being automatically fed to the grid. In the case of car parking areas and marinas, large available spaces which are usually clear of trees or other obstacles could provide space for ground installed turbines whereas in the case of garages, turbines can be installed on the building as well. These, already tested in the US, concepts have proven to work satisfactorily and coupled with the numerous marinas and

docks of mainland and insular Greece could yield significant amounts of energy. In the last case of Street Lamps, VAWT could be installed on highway lighting poles or lane separators and take advantage of the wind currents created by traffic (concept study). Figure 37 exemplifies such applications in the UK, US and also presents a highway light pole concept art image:



Figure 37: On-grid lighting applications (Speck, 2008; Meinhold, 2010; Voelcker, 2010)

In the case of On-grid applications, small wind turbines could act as a form of additional auxiliary energy source in cases of emergency. When the grid is operating all energy production can be sold at guaranteed prices but when the grid experiences a fault causing a local blackout, the energy production can directly feed the housing building and cover essential energy needs such as emergency lighting. The concept can be extended in highways where in the case of a grid fault, nearby located SWT could provide power to electrical message boards and traffic lights. When turbines are also coupled with storage devices this concept could provide adequate autonomy even when operating under the lowest of wind velocities.

A different application for On-grid SWT can be identified when small turbines are to be mounted on corporate buildings located inside urban centers. Although the technological implementation remains the same as before, the focus is shifted from the revenue gained from directly selling electricity to the grid, to the unique opportunity presented to companies to promote their *Corporate Social Responsibility (CSR)* role. CSR is defined as the "organization's obligation to maximize its positive impact and minimize its negative effects in being a contributing member to society, with concern for society's long-term needs and wants" (Lantos, 2001). Many companies have already embraced the promotion of Sustainability as part of their CSR policy, through adopting measures in an effort to reduce their carbon footprint and produce eco-friendlier products. The adoption of this form of energy production could be characterized as another measure to further this effort. Studies have shown that a relation between CSR and corporate financial performance exists and also have concluded that by demonstrating social or environmental responsibility, corporations can be financially benefited (Orlitzky, Schmidt, & Rynes, 2003). Thus it can be deduced that corporations which will choose to implement SWT will be eventually financially benefited. Since the implementation of SWT could be regarded as an indirect form of corporate advertise, it could be also

incorporated in the company's marketing strategy and capital funds could be drawn from the respective department. Thus an entire market could be eventually realized boosting the particular RET in the country. More details regarding this application are given in Chapter 5.

Small wind turbines have distinguished themselves in the role of Off-grid electricity production application for decades. Especially in the cases of US farms and Chinese nomadic herdsmen, they have historically been the primary source of energy in the absence of a rural utility grid (GIPE, 2004). Also in 2009 Off-grid units comprised 97% of the Chinese small wind turbine market while over 80 % of worldwide manufacturers produce stand alone systems (World Wind Energy Association, 2013) indicating that Offgrid applications have and will continue to play a major role in the establishment of this technology. Nonetheless today small wind turbines, apart from their traditional role of providing a reliable technological solution for the establishment of autonomy and the realization of emergency energy backup systems for households and farms located in remote areas, can be used in different urban-located, Off-grid, local, low power applications as well.

Regardless of the application, when Off-grid use is considered, energy storage is mandatory. Due to the intermittent nature of the wind, the generator of the wind turbine cannot always provide the required power output or cannot provide a constant value power output (more on the subject to be discussed in the technological barrier related chapter). Despite the above the advantage of implementing storage (in most cases batteries) can be the later use of high production surplus over extended low wind time periods. This fact essentially increases the efficiency of the system by minimizing the energy to be discarded as dump and increasing autonomy. Also it is worth noticing that an auxiliary power supply (such as Photovoltaics) often is installed apart from the wind turbines in order to compensate for energy when low wind velocities result in diminished or inadequate energy production and to ensure that the battery's Depth of discharge (DOD), or the percentage of battery capacity that has been discharged expressed as a percentage of maximum capacity, will not reach or surpass 80%. In that case the battery is said to have entered Deep discharge which crucially diminishes the battery's Cycle life, or the number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria (MIT Electric Vehicle Team, 2008). Even if Deep discharge is avoided, operating at high DOD reduces significantly the Cycle-life of a battery (Appendix) which essentially means a battery replacement will be required every few years, thus increasing the overall variable costs. Since wind velocities may drop significantly for several days, a small auxiliary energy source will ensure that the battery operates at a low DOD percentage and will need to be replaced occasionally thus minimizing this occurring cost. Thus when autonomy is the end goal of the application, Hybrid systems are most common.

In the case of Greece, Off-grid small wind turbine applications present remarkable potential. As explained in previous chapters, the most favorable wind regime of the country is found in the thousand islands which in their overwhelming majority still are not interconnected with the mainland grid and are dependent on oil (Diesel) based conventional energy production methods for which the fuel is entirely imported since there is no indigenous production. Also the country is mountainous, with areas being still difficult to connect to the utility grid. Thus by taking into account the previous facts, the following Off-grid applications can be identified for the case of Greece (World Wind Energy Association, 2013):

- Electrification of non-interconnected inhabited islands
- Electrification of non-interconnected inhabited mainland areas
- Electrification of remote Telecommunication sites
- Pumping Stations
- Desalination and purification systems
- Military applications
- Mobile applications
- Low power no storage applications

With the inability to install large-scale wind farms due to lack of infrastructure, the only possible manner of exploiting the vast wind potential of the non-interconnected islands lies through the use of SWT. Villages and remote settlements which up until now have depended on diesel generators can ensure autonomy by implementing individually SWT or by creating SWT-based *smart grids*. In the latter case, turbines (along with other energy sources and storage devices) are installed in more than one household which are electrically interconnected forming a small grid. According to its time dependent power requirements and production, each household can act as a supplier or consumer. Power electronics can be employed for the electricity production, transmission and distribution management and control.

In the Hellenic mainland few areas are currently not connected with the utility grid. Nonetheless in some cases of remote country houses or other settlements such as livestock farms, where the cost of connecting to the grid may be discouragingly high, autonomy through implementation of RET such as SWT may provide a less costly option. Especially regarding remote mountainous areas where usually high (400-150kV) or medium voltage (20kV) power lines exist, due to the difficulty of the grid operator to connect power lines which will transport low voltage (230V) electricity to the household without charging the end user the cost of a transformer, SWT based autonomous systems could provide a feasible option. Either for powering lighting and household appliances or for charging electrical fences, storage is mandatory for these applications, so hybrid systems are best suited.

Powering remote Telecommunication sites has proven to be a feasible application in other countries such as in the mountainous frontiers of Chile and Argentina shown in Figure 38. Also agricultural applications such as pumping water from wells could draw power from small turbines. In the case of Greece both applications could be most efficient in the above discussed remote non interconnected regions.

An interesting application which could provide a sustainable solution to the problem of drought or water scarcity due to depletion of water reserves caused by tourism overpopulation of small noninterconnected islands of Cyclades in the Aegean Sea during summer months, is desalination-purification of sea water by the use of small wind turbines. In the specific region, large amounts of fresh water are transported every year, presenting a high yearly cost. Already attempts have been made to harvest the energy of the wind for such applications with the most successful being the construction of a floating desalination unit near the small island of Irakleia which still operates since 2007. The pilot project named "*Hydriada*" influenced from the Greek mythology (Figure 39), implements a 30KW wind turbine to produces and supply, through advanced electrical and electronic energy conversion components, energy to a desalination unit that uses a reverse osmosis technique to produce 70,000 liters of potable water from the sea on a daily basis (Lilas & Nikitakos, 2008). Small wind turbines can be used in hybrid systems for security-surveillance systems, especially in forested areas for fire detection. Due to the thick foliage photovoltaic systems tend to have reduced efficiencies and thus the use of small wind turbines can provide adequate electrical energy to power thermal cameras. This hybrid off grid systems are currently in use in some forested areas of the country.

Remote military bases, outpost and camps are spread over the Hellenic region. SWT could provide a feasible option for establishing energy autonomy without the need for fossil fuel transportation, thus greatly reducing costs and increasing undisturbed independent operation. Already RET based outposts exist, such as the "Agios Nikolaos" outpost at the remote island of Kalolymnos which claims autonomy granted by a hybrid system utilizing small wind turbines, photovoltaics and desalination units (Hellenic Army General Staff, 2012). Mobile applications, such as portable small turbines to be used in the field of operations, could further the use of this RET in the military but the technology is still far from being implemented in such a manner.



Figure 38: Telecommunication site powered by Small Turbine and PVs (Gipe, Small Wind Systems and their Applications: An Overview, 2004)



Figure 39: Hydriada desalination unit (www.ftiaxno.gr, 2011)

Although uncommon, in some specific Off-grid uses, storage may not be required. Such applications where rather low power amounts are needed include cathodic protection for pipelines. A small electric charge can counteract galvanic corrosion in highly reactive soils and since the process of corrosion is slow, any short time lack of wind (and thus lack of charge) does not affect the protection of the pipelines (Gipe, 2004). With an expanding natural gas pipeline grid, such an application could be promising in remote areas.

3.6.3 Business Groups

3.6.3.1 Companies

Greece has an undoubtedly favorable wind potential and numerous applications for which small wind turbines could be implemented. Despite this fact the Hellenic SWT market has not been able to grow as compared to other competitive RET markets aiming for small local power production due to barriers which are to be analyzed in following sections. Nonetheless the research conducted during this thesis revealed more than 220 firms and technical offices claiming to be involved with the conduction of technical studies and installation of small wind turbines ($\Pi PA\Sigma INO \Sigma\Pi ITI \& KTHPIO, 2013$).

After contacting HEDNO, the Operator for the Non-Interconnected Islands, the Center for Renewable Sources and Saving (CRES) as well as the key lobby for the promotion of wind energy in Greece, Hellenic Wind Energy Association (HWEA), it was determined that the only current report which includes information regarding active Hellenic companies was the HWEA's Catalogue for Registered Small Wind Turbine Affiliated Companies (Hellenic Wind Energy Association, 2012). The report, apart from data regarding company name, contact information, product information and additional services provided beyond the manufacturing / sales / representation for small SWT (studies, project planning, licensing, etc.) did not include specific data regarding the business activities of these companies as well as the status of this market, such as number of On and Off grid installed turbines over Greece, the number of total installed capacity for On-grid and Off-grid applications, the number of installed capacity over the last five years of economic crisis and other valuable information. Furthermore as stated in the report, gathered data are incomplete and potential investors are encouraged to conduct a detailed market research (Hellenic Wind Energy Association, 2012). Apart from this report, the only available information provided by Hellenic authorities and namely by the site of HEDNO, were regarding the 958 requests for connection to the interconnected or non-interconnected grid which have been issued since 2010, indicating a heightened interest on the technology. All request concern turbines of nominal power higher than 20kW and more specifically over 95% concern turbines of 50kW nominal power. Nonetheless, none of these requests have yet received further authorization for connection and installation (HEDNO, 2013) since they have been put on hold due to a new imminent RES Law, which is to be passed in 2013-2014. Regarding the further lack of data for small wind turbines, it is worth noting that since most small wind turbines in Greece have been installed for Off-grid applications and thus companies are not required to provide specific information to the Grid Operator by legislation (since no request for connection to the grid is issued), official data are not available by according sources. Finally, installed On Grid turbines of less than or equal to 1kW, which aim to reduce the consumption from conventional means, also exist but according to information from companies, are not declared to the Network Operator. Due to the above difficulties, an investigation was

conducted, in an effort to gather and quantify such data and present a more accurate overview of the Hellenic SWT market.

Gathered data are presented in Table 11. The companies which were identified are currently involved with the construction, manufacturing or trading and representation of foreign manufacturing firms for providing turn-key solutions regarding small wind turbine for On-grid and Off-grid applications. The investigation isolated and focused on twenty one (21) companies which were willing to provide data, in a total of thirty two (32) companies directly being contacted by the author. Following the philosophy of HWEA's report (*Catalogue for Registered Small Wind Turbine Affiliated Companies*), companies which solely conduct technical studies, issuing of licenses and installation were not considered during this investigation. If these companies were taken into account, the number of installed small turbines is reasonably expected to be higher than the total number of installed small wind turbines presented.

By the information gathered from Table 11 and after cross checking the reliability of above data via contacting HEDNO and the Operator for the Non-Interconnected Islands (only for On-Grid SWT) the following small wind turbines, connected to the Mainland Network Grid (authority of HEDNO) and Non-Interconnected Network Grid (authority of ONII) for On-Grid applications, were determined:

- 1. Two (2) small turbines of twenty (20)kW nominal power each in Crete
- 2. Two (2) small turbine of ten (10)kW nominal power in Crete
- 3. One (1) small turbine of twenty (20)kW nominal power in Saint Efstratios (the first "Green" Island pilot project in Greece) owned by CRES
- 4. One (1) small turbine of twenty (20)kW nominal power in Chios
- 5. Six (6) small wind turbines of forty (40)kW total nominal power in the Lavrion Technological and Cultural Park (LTCP)
- 6. One (1) small turbine of one (1)kW nominal power in Attica

The turbines located in in LTCP were installed for research purposes by ARESTI Power and thus, although connected, do not sell energy to the grid. The same applies to the one turbine of 1kW power installed by HSB where energy is being consumed by the producer thus reducing the amount of energy consumed conventionally via the grid and thus achieving a reduction on the final electricity bill. Regarding the rest of On-grid turbines located in Non-Interconnected Islands, their current Operational status is unknown.

A specific analysis was conducted regarding the barriers identified by these twenty one companies, which is presented along with the results of the investigation separately in Chapter 4. Due to their significance for the completion of this thesis, the barriers mentioned by Hellenic companies were categorized based on the applied framework of analysis (to be described in Chapter 4) and conclusions were drawn on the perceived predominant obstacle due to which the establishment of this technology has not yet occurred in the Hellenic small scale RES energy market.

Company	Years Of Operation	Total installed wind turbines	Total installed capacity (kW)	Installed wind turbines in the last 5 years	Installed capacity in the last 5 years (kW)	On-grid / Off-grid	Producers consumes and sells surplus or directly sells	Location of installation	CSR oriented	CSR could work in Greece	Applications	Price Range (€) of provided products
2EN Enallaktiki Energiaki	10	0	0	0	0	-	-	-	no	no	Households ,Fields	-
ACCD	8	30-40	70-100	30-40	15	Off grid	-	Mountainous areas of Halkidiki, Mount Athos	no	no	Telecommunications, autonomy for households	5000 - 40000
Applitech	3	2	40	2	40	On grid	Direct Selling to the grid	Crete	no	yes	Households, Fields	150000
Aresti Power	6	240	220	210	210	On/Off grid	Surplus Selling	All over Greece	no	yes	Telecommunications, autonomy for households	3000-150000
Autoenergy	3	0	0	0	0	-	-	-	no	no	Autonomy for households	15000-25000
A VECO	6	50-60	500	50-60	500	Off grid	-	Evia, Attika, Voitia	no	yes	Telecommunications, autonomy for households	800-240000
Cocoon Solar Energy S.A	8	30	60	30	60	Off grid	-	All over Greece	no	yes	Telecommunications, autonomy for households	3000-5000
Compa Solar	13	80	80	20	20	Off grid	-	Northern Greece, Islands	no	yes	Telecommunications, autonomy for households, businesses, security/survailance	3000-5000
Energeiaki Piliou	24	10	15	5	7,5	Off grid	-	All Over Greece	no	no	All applications	2000-200000

Table 11: Hellenic Companies involved in the construction, manufacturing, trading and representation of small wind turbine foreign and domestic firms

Energotech S.A	35	>300	>500	10	15	On/Off grid	Both	All over Greece, certain EU countries	no	no	All applications	2000-240000
Entec	7	2	20	2	20	On grid	Both	Herakleion Crete	no	yes	Households, Fields	150000-200000
Engaia	6	0	0	0	0	-	-	-	no	no	All applications	-
Georythymiki	4	3	1,1	3	1,1	Off grid	-	Peloponese, Central Greece	no	yes	Autonomy for households	2000-3000
HELIOSRES	5	2	2	2	2	Off grid	-	Attika	no	yes	Households, Industrial Buildings	2000-250000
HSB	4	3	2	3	2	On/Off grid	-	Attica, Central Greece	no	yes	Household Applications	3000
Iliako Reuma	15	12	7	1	1	Off grid	-	Crete	no	no	Autonomy for households	4000-40000
KRITON	<1	0	0	0	0	-	-	-	no	yes	All applications	3000-100000
PALS	15	100	60	50	20	Off grid	-	Attika, Aegean Islands, Crete	no		Households, Hotel Units	1500
Photovoltaic	20	50	<40	-	-	Off grid	-	Central and Southern Greece, Agean Islands	no	yes	Autonomy for households and remote islandic settlements	4000
Renevol	1	0	0	0	0	-	-	-	no	no	Households, industrial sites, fields	200000
solar.com.gr	10	27	55	12	24	Off grid	-	Zakynthos, Macedonia, Attika	no	yes	Autonomy for households	5000

As identified by the conducted research, 66,7% of companies have been in operation for over 5 years, indicating that the majority of companies in the Hellenic region were already established before the financial crisis. Also eight companies were identified to have experience in the field for over 10 years. From the rest of companies operating for less than five years, only two were identified to have been issued during the last year. No wind turbines have been implemented by these companies. By considering the data provided by Table 11, over 950 small wind turbines have been installed in high wind potential areas of Greece by the mentioned companies with the vast majority implemented for Off-grid applications. Practically only five companies have installed turbines for other than Off-grid applications during their years of operation. Of interest is the fact that a substantial number of turbines have been installed during the last five years of economic crisis despite the shrinking of business activities and investments in the country. Nonetheless the installed capacity originating from these turbines represents less than 1MW of power.

The applications, small turbines have been implemented for, are in accordance to the ones identified by the previous chapter. The majority of autonomous systems regard households, fields and small businesses such as hotels and aquaculture units. Also turbines have been used in hybrid systems for powering of remote telecommunication sites and surveillance systems. No turbine has been implemented for the demonstration of a developed CSR in the country. In fact not a single company was defined as focusing on business cases which could incorporate SWT to earn revenue in manners other than the direct energy selling or reduction of consumption. The reasons for this lack of selling policy/strategy will be identified in following chapters. Nonetheless the majority of companies (85%) were positive towards such indirect earning methods, as long as a sufficiently promoting and clearly defined legislative framework that would ensure the safe and rational use of Small wind turbines is to be provided.

By identifying the pricing of products from each company, a range of Capital Costs was determined. These costs which include the rotor, tower, supporting infrastructure, electrical equipment, installation costs and other upfront costs were estimated to be equal to 2500 to $5000 \in$ per kW. These values are validated by literature as well (Georgakopoulos T., 2011).

The research has indicated that a high consumer interest exists both for off and on grid applications. Regarding the latter category the interest indicated by the large number of issued requests for connection, is mainly attributed to the highly promotional FIT introduced by law 3851/2010 which rendered such investments as highly attractive. Nonetheless the industry has not been able to expand and mature on grid connected systems for reason further to be explained in later chapters. The data presented in Table 11 have revealed that during the last five years of economic crisis induced fiscal reforms and low economic growth, the Hellenic small wind turbine market has been sustained only by off grid implementations where smaller nominal output power, and thus lower capital cost, turbines are used. The wind potential of the islands has only been exploited locally for autonomous hybrid systems but a number of companies claimed installed turbines at relevant sites.

3.6.3.2 Products

The Hellenic companies identified by the research conducted during this thesis were identified to offer a variety of turbine models of different technical characteristics, suitable for both On and Off grid applications. All companies included in Table 11, with the exception of Energotech, are suppliers of small

wind turbine models which are imported to Greece from UK, Germany, Denmark, Netherlands, Sweden, China, Korea, Canada and the US. Thus all major manufacturing countries are identified in the Hellenic market but also manufacturers from other countries which could either introduce novelties in their turbine designs or competitive prices. Among manufacturers which are represented in the country, the following well established brands are included: *Aelos, Aerofortis, Aiolos, Air Breeze, Air-X, Antaris, ENWIA, Ettes, Future, Energy, Greatwatt, Hummer, Kingspan Wind, Phono wind, Polaris,Proven, Redriven, Ropatech, Seaforth Energy, Silentwind, Southwest, Sunnily, Urban Green Energy (UGE), Whisper, Wind Energy Solutions(WES), Winden.*

The Hellenic market, in spite of the presence of various small wind turbine related companies, was identified to have all but one SWT manufacturer. The company Energyworks S.A, which is also the most experienced in the field with over 30 years of presence, is responsible for the creation of a downwind horizontal axis turbine model ranging from 1kW to 6kW nominal power (Butterfly®), pictures of which are presented in the Appendix. The model has patented various innovative design features, such as a variable rotor diameter size and an active orientation system.

The Hellenic market turbine models have a nominal power output range from only 200watt to 50kW, thus covering all possible applications. More analytically the percentage of all companies which offer turbines below 1kW power, 1-10kW and 10-50kW are presented in Figure 40. Also to understand the percentage of companies which offer products of only a specific power output range, Figure 41 is presented. Figure 41 can indicate the number of companies which target specific applications (e.g. companies which offer only products of less than 1 kW power output target Off grid applications whereas companies which offer only above 10kW to 50kW are most likely to target On grid applications).



Figure 40: Percentages of all companies offering turbines of according power output level



Figure 41: Percentages of all companies offering turbines of according specific power output level

By Figure 40 it is observed that among all companies, turbines of different power level are equally represented which practically translates into the fact a consumer could find as many companies providing less than 1kW nominal power energy as companies providing turbines which reach 50kW of nominal power. This equal distribution of turbine types which covers all possible ranges and applications signals a more mature, in terms of product supply, market.

By observing Figure 41 it can be understood that the majority of existing companies (33%) offer products which range from few hundred Watt power outputs to 50kW. This fact indicates that such companies possess the technical knowledge and know how to complete different installation which could range from installing a turbine on a rooftop to building a 30 meter tower for the implementation of a much larger machine. Only a small percentage (9%) of companies deals exclusively with less than 1kW of power machines. These companies focus almost solely to Off grid applications and namely to the establishment of autonomy via hybrid PV-Wind Energy systems as well as mobile applications such as boat chargers. A more substantial percentage of companies (19%), focus solely to large power output turbines over 10kW to 50kW. Despite the fact that only a very small number of such turbines has been actually connected to the grid in order to sell electricity and despite the number of requests for connection which have been suspended until a new legislation is submitted and passed, this percentage indicates a fair number of companies which still support such SWT applications. Finally the companies which provide machines of less than 1kW to 10kW as well as those which provide above 1kW to 50kW of nominal output power were identified to obtain percentages of 29% and 10% accordingly. Companies in these categories offer products which focus on implementation for autonomous buildings and hybrid systems as well as but either do not include low or high power output products thus limiting implementation possibilities.

Following the trend of manufacturing companies worldwide regarding the preference of axis of rotation orientation, Horizontal axis machines are preferred over Vertical axis ones by Hellenic suppliers and manufacturers. The following Figure presents the percentage of companies offering either Horizontal,



Vertical axis or both types of products. No hybrid type of turbine was identified to be commercially provided in Greece. The predominance of HAWT is evident.

Figure 42: Percentage of companies supplying different axis orientation turbine types

3.7 Economic Potential of SWT in Greece

The Hellenic Small Wind Turbine Market presents substantial technological potential due to the country's abundant natural resources. Furthermore, an existing (but not applied) favorable, in terms of feed-in tariffs, legislative framework exists which has provided economic incentives for the use and promotion of this technology. Also a niche market consisting of a non-trivial number of companies (with regard to Greece's demographic, land and small scale RET status characteristics) has been established. In this chapter the economic aspects of implementation of SWT in the Hellenic energy production regime will be analyzed. The analysis concerns Grid connected horizontal axis turbines which aim to sell electricity at guaranteed prices and are implemented as revenue driven investments. The data presented provide a simplified yet indicative overview of characteristic economic parameter's value ranges, as identified mainly by reports and presentations issued by HWEA. Specific official techno economic data were unable to be identified since even authorities such as RAE which publish monthly report with detailed estimations and calculations of investment evaluation parameters based on real data of Hellenic Market, such as the Internal Rate of Return, do not treat SWT separately from Large scale wind energy or do not consider them in according calculations at all.

As described in previous chapters, the economics of wind turbines are mainly governed by the annual energy production which essentially determines the revenue obtained, in the case of On-Grid systems. Although the energy production is a function of a number of parameters, such as the wind speed velocity and the frequency of occurrence of these velocities at a specific site (Weibull Distribution), the capacity factor of a specific site, the operational characteristics (namely the power curve, height, axis orientation, rotor diameter etc.) of the turbine and how they match the wind regime of a specific site, the ground roughness and obstruction or turbulence caused by surrounding environment affect the power production, values for the average annual energy yield for a mean wind velocity of 7m/s are provided in Table 12. The

values presented, concern wind turbines of 10kW, 20 kW (interpolated) and 50kW which have been provided by HWEA and aim as indicative ranges.

Rated Power (kW)	Indicative Energy output (kWh)
10	30000
20	60000
50	150000

Table 12: Indicative Energy Production Values (Hellenic Wind Energy Association, 2012)

Furthermore to demonstrate the relation of annual energy production as a function of different parameters and namely the rotor diameter and wind velocity, Figure 43 is presented, which takes into account data from three different 50kW wind turbine models (Georgakopoulos A. , 2011). As it can be identified by the graph, the increase of diameter and of wind speed increases the energy production almost linearly. This relation can be assumed to hold for wind turbines of smaller rated power as well and thus conclusions regarding smaller machines will be based on the particular 50kW turbine data. In order to facilitate further calculations, the average energy yield per velocity (in purple) has been calculated and taken into account.

As identified by Table 11 the typical cost for a 50 kW turbine is equal to approximately 150000 to $250000 \varepsilon \cdot$ values which correspond to the data provided by HWEA (Georgakopoulos A. , 2011). If a cost analysis is performed, the key Capital cost parameters (since the cost of land purchase or rental does not apply to the majority of cases, it is not considered), with corresponding representing price ranges, for a 50kW would be (Georgakopoulos A. , 2011):

- The cost for purchasing the Wind Turbine: 80000-170000€
- Construction/Installation Works: 25000-40000€
- Cost for connection to the Network: 10000-20000€
- Costs for technical study and license issuance: $10000 \in$

Thus it can be summarized that a representing range for the installation of a 50kW turbine can be narrowed to $125000-240000 \in$. By assuming the issued highly promoting feed in tariff of Law 3851/2010 (without any further increase on the 2010 price) presented in Table 9, the simple payback time (as described by formula 2.24) can be estimated by taking into account the average annual energy production per average wind speed of Figure 43 (purple trend line).

The below values do not take into account parameters such as variable/running O&M (scheduled) costs or the time-varying nature of cash-flows. Also they do not take into account possible subsidy, tax credits or other financial benefits apart from the guaranteed feed in tariff of Law 3851/2010. As such the

presented simple payback time values must be considered as *minimum* theoretical values aiming to serve the purpose of Simplified Method Economic Models.

It should be noted though that when additional costs are included and when a more accurate calculation of the annual energy yield (including the per site availability effects in the capacity factor) the predicted payback time can increase. By information provided by companies, the calculated payback time regarding 50kW turbines operating at an average annual wind speed of 6m/s can reach 8 to 10 years(according to the turbine and site specifications).



Figure 43: Annual production of three different rotor diameter 50 kW turbines per wind speed (Georgakopoulos A. , 2011)



Figure 44: Simple Payback Time ranges for 50 kW Average Annual Energy Production

A large variation can be observed on payback time, especially regarding small wind potentials. This substantial difference is attributed to the steady ratio of different assumed Capital Cost range values. All payback time values for an assumed Capital Cost of $240000 \in$ are 1,92 times higher than the corresponding values for an assumed Capital Cost of $150000 \in$. Nonetheless the effect of this difference on the evaluation of a potential investment is diminished as the wind potential increases and thus payback time decreases. As identified by HWEA the evaluation of a SWT investment based on simple payback time can be classified as:

Wind Potential	Investment Characterization	Payback Time
4 - 5,5 (Low)	Little Interest	8 - 11
5,5 - 7 (Medium)	Attractive	6 - 8
7-9 (High)	Very Attactive	4 - 6
> 9 (Very High)	Excellent	< 4

Table 13: Investment Evaluation based on Payback Time (Georgakopoulos T., 2011)

According to Table 13 and Figure 44, when the average annual wind velocities are equal or above 5,5 m/s, the potential investment can be primarily be evaluated as attractive. By combining the above fact with the wind potential of Greece, best described by Figure 36, it can be deduced that SWT could present a viable investment. Important is the fact that SWT operate ideally at between medium and high wind velocities. Thus at higher wind speeds the effects of reduced availability (or increased down time of the turbine during which it will not produce energy) due to the inability of the turbine to cope with such velocities or rapid air flow direction changes at such speed, will affect significantly the annual production and thus increase the payback time.

In order to include the effect of O&M costs as well as determine a representative range of values regarding the cost per produced kWh per annual average wind speed if all parameters are kept constant in time, a calculation of the Simple Cost of Energy is performed, as defined by formula (2.26). Also the Generation Costs are calculated according to equation (2.27). The annual O&M costs are estimated as 2% of the initiall Capital Cost (Walter Hulshorst, 2013) and an average annual charge factor (FCR) accounting for utility debt, equity costs, taxes of 15% has been considered. The results of this calculation are presented in Figure 45 where data regarding the average energy yield per velocity (purple tend line) of Figure 43 have been taken into account.



Figure 45: Simple Cost Of Enery ranges for 50 kW Average Annual Energy Production

The above Figure indicates that the costs per MWh are prohibitive regarding sites with wind velocities smaller than 7m/sec in the case of a Capital Cost equal to $240000 \in$. In this case the FIT price of $250 \in /MWh$ is marginally higher than the costs per MWh and theoretically could provide profits, although not enough to provide payback during the lifetime of the project. Regarding smaller Capital Cost ranges the Cost of Energy is smaller than the FIT price even from 5,5 m/s wind speeds although again could provide substantial profit when the average nominal wind speeds are over 6,5 m/sec.



Figure 46 Generation Cost of Enery ranges for 50 kW Average Annual Energy Production

Regarding the results of Figure 46, the generated costs are below the guaranteed feed in tariff but also well above the cost of electricity provided by conventional means. Generation Costs per conventional fuel source in Greece are provided in Table 14, as taken by the "CASES" N.T.U.A program (Vrazitouli & Oikonomou, 2010). It should be noted that these price do not include external costs for CO_2 emissions or other externalities. Also in Greece the residential, commercial and industrial electricity market prices not including transmission through Network and System charges, administrative charges and all taxes which would be approximately common for RES as well, as provided by PPC, are given in Table 15 (When all charges are added the price of retail (end-user) energy prices for households in Greece is equal to $0,14073 \notin kWh$ (Europe's Energy Portal, 2013) which is below the 27 EU average of $0,197 \notin$ for household consumers and $0,118 \notin$ for industrial users (Eurostat, 2013)). By observing the prices presented in Table 14 and Table 15, SWT cannot be yet competitive without a FIT system. Nonetheless if the costs of small wind energy systems continue to decrease while the cost of electricity increases and provided of the existence of a supporting financial policy, the generation costs for wind energy systems operating under wind regimes of average annual wind speed over 7 m/sec, could eventually become competitive with residential electricity prices.

Table 14: Electricity Generation Costs for 2010-2020 (Vrazitouli & Oikonomou, 2010)

	Fuel			
Electricity	Lignite	Natural Gas	Diesel	
Generation Costs (€/kWh)	0,0278	0,0458	0,0719	

Table 15: Electricity Prices for Low Voltage by PPC S.A (PPC SA, 2013)

	Commercial	Industrial			
	0-800 kWh	801-2000 kWh	> 2000 kWh		
Energy Prices of PPC (€/kWh)	0,07793	0,0946	0,10252	0,10801	0,10347

It must be noted that the results which produce the most realistic approximations are those of the upper range values in Figures 44, Figure 45 and Figure 46 since a number of parameters which would have increased the cost more towards the upper range limit, have been omitted from calculations. Nonetheless the presented value ranges indicate the high economic potential of 50 kW small wind turbines as formed by the high feed in tariff of $250 \notin$ /MWh. Regarding the use of smaller wind turbines due to smaller energy productions, estimated Payback time, Cost of Energy and Generation of energy are expected to obtain higher values, thus presenting less competitive investment options.

In order to evaluate the cost of wind energy more realistically by incorporating the time value of money, the Levelized Production Cost (LPC) is calculated for a 50kW turbine, based on formula (2.35) for each expected average annual energy production per average wind speed of Figure 43 (purple trend line). The assumptions taken for this calculation are:

- Annual O&M costs are constant and equal to 3% of the Initial Capital Cost (European Wind Energy Association, 2009)
- Annual energy production is constant
- The discount rate is assumed to be equal to 5% (European Wind Energy Association, 2009)
- Depreciation is not taken into account
- Capital Costs are assumed to be equal to the upper range of 240000€ (Georgakopoulos A. , 2011)
- The Economic Lifetime is assumed to be equal to 20 years
- Availability is assumed to be equal to 96% (high value)

LPC as a function of the annual average energy yield per average annual wind speed is presented in the following Figure:



Figure 47: LPC for 50 kW Average Annual Energy Production per Average Annual Wind Velocity

The graph shows the cost of energy is higher in almost every average wind speed than the the cost of electricity provided by conventional means. Nonetheless the current FIT system of $0,25 \in /kWh$ could sustain a viable investment when wind speeds are above 6m/sec (LPC< $0,217 \in /kWh$) by providing an annual income (FIT price minus LPC) ranging from $0,05 \in /kWh$ to $0,13 \in /kWh$ depending on the annual average speed and annual produced energy.

In order to further evaluate the Internal Rate of Return or IRR as a function of the Capacity Factor, for the case of a Greek island, the software RETScreen 4 International® was used. RETScreen is a free software created by numerous experts in the field of can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs) (RETScreen International, 2013). The analysis conducted took into account a capacity factor of 30% according to bibliography (Boccard, 2009) and three scenarios which progressively produce smaller IRR values.

Common elements for all scenarios are the economic evaluation of a 50kW ReDriven wind turbine located at the Aegean island of Milos (location characteristics as provided by RETScreen 4 are found in the Appendix). The wind turbine characteristics, as provided by the Library of RETScreen 4, are shown in the Table below:

Wind turbine						
Power capacity per turbine	kW 50,0					
Manufacturer	R	eDriven				
Model	50 KW					
Number of turbines	1					
Power capacity	kW	50,0				
Hub height	m	18,0	$6,9 \mathrm{~m/s}$			
Rotor diameter per turbine	or diameter per turbine m		14			
Swept area per turbine	m ² 154					
Energy curve data	S	tandard				
Shape factor		2,0				

Table 16: ReDriven 50kW turbine characteristics provided by RETScreen 4 software

The Shape factor is assumed to be equal to 2 since the location is considered to be near the coast of the island. The wind speed at Hub Height is equal to 6.9 m/s by considering the Wind shear effect (equation 2.18) and by taking into account the annual wind speed of 6.7 m/sec at 10 meters reference height, the height of the turbine equal to 18 meters and the roughness length or Wind Shear exponent equal to 0.03. The according power curve and energy curve data as a function of the wind speed and the location data above are presented in the following Figure (numerical data are presented in the Appendix):



Figure 48: ReDriven power and energy curve as provided by RETScreen 4 software

By the above considerations a gross annual energy production of 157MWh is determined which effectively translates into 132MWh of electricity exported to the grid.

Regarding the financial parameters, all scenarios include upfront Capital cost of $240000 \notin$, $7200 \notin$ of annual O&M costs (3% of Capital Costs), an inflation rate equal to 1,5% (RAE, 2013), and a project lifetime equal to 20 years. Also the Feed in Tariff price defined by Law 3851/2010 is taken into account but with an adjustment for 2013 prices (RAE, 2013). Thus a price equal to $256 \notin$ /MWh is regarded while no further incentives or grants are taken into account. The three scenarios follow the below considerations

- 1. A loan is taken by the potential buyer which includes a debt ratio of 60% (the ratio of debt over the sum of the debt and the equity of a project), a debt interest rate of 8% and the number of years over which the debt is repaid equal to 20 years
- 2. A loan is taken by the potential buyer which includes a debt ratio of 50% (the ratio of debt over the sum of the debt and the equity of a project), a debt interest rate of 10% and the number of years over which the debt is repaid equal to 15 years
- 3. No loan is taken by the potential investor and the project is self- funded entirely

The results for all scenarios are given below. Each scenario includes a Table which presents the according Financial Analysis parameters while the graphical representation of Cumulative Cash flows is provided as well. In all graphs the cash flows begin negative, since they represent the upfront costs of the first year of the investment, start to become positive since income is produced each year and subsequently become zero meaning the investment has "broken even" or the NPV has become equal to zero. It follows that a higher IRR presents a faster balancing of costs and revenue. Nonetheless it does not reveal whether an investment will yield higher revenue in its entire lifetime. Before continuing to the analysis it must be noted that the debt interest rate, in the cases where the investment is not entirely funded by equity, has received higher values than the most expected 5% which is considered in the majority of wind turbine projects. The deliberate choice of using an 8% and 10% debt interest rate aims at representing the real economic state of Greece where loans are very hard to impossible to be provided for such type of investments. This difficulty or unlikeliness in obtaining a loan is thus expressed in such a manner.

RETScreen 4, in order to present the financial viability of a project, performs a distinction between Equity IRR and Assets IRR. In the first case of the Equity IRR (also referred to as Return on Investment (ROI)), when the project is funded by a mix of debt and equity, the model calculates the pre-tax internal rate of return (IRR) on equity (%) or money directly spent and not loaned by the investor, which represents the true interest yield provided by the project equity over its lifetime. The determination of the IRR is performed by finding the discount rate that causes the net present value of the equity to be equal to zero (RETScreen 4, 2013). In the second case of Assets IRR (also referred to as Return on Assets (ROA)) the model calculates the pre-tax internal rate of return (IRR) on assets (%), which represents the true interest yield provided by the project assets over its life (RETScreen 4, 2013). In case no loan has been undertaken only the Assets IRR is provided by the model since it becomes equal to the Equity IRR.

<u>Scenario 1</u>

Table 17: Scenario 1 Evaluated Financial Parameters

Financial parameters						
Inflation rate	%	1,5%				
Project life	yr	20				
Debt ratio	%	60%				
Debt interest rate	%	8,00%				
Debt term	yr	20				
Total initial costs						
Capital Costs	€	240.000				
Annual costs and debt payments						
O&M (savings) costs	€	7.200				
Debt payments - 20 yrs	€	14.667				
Total annual costs	€	21.867				
Annual savings and income		·				
Electricity export income	€	33.679				
Total annual savings and income	€	33.679				
Financial viability						
Pre-tax IRR - equity	%	14,1%				
Pre-tax IRR - assets	%	2,9%				
Simple payback	yr	9,1				
Equity payback	yr	7,1				



Figure 49: Scenario 1 Cash Flow graphs showing cash inflows and outflows during investments lifetime

<u>Scenario 2</u>

Table 18: Scenario 2 Evaluated Financial Parameters

Financial parameters						
Inflation rate	%	1,5%				
Project life	yr	20				
Debt ratio	%	50%				
Debt interest rate	%	$10,\!00\%$				
Debt term	yr	15				
Total initial costs	· · · · ·					
Capital Costs	€	240.000				
Annual costs and debt payments						
O&M (savings) costs	€	7.200				
Debt payments - 15 yrs	€	15.777				
Total annual costs	€	22.977				
Annual savings and incom	ne					
Electricity export income	€	33.679				
Total annual savings and income	€	33.679				
Financial viability						
Pre-tax IRR - equity	%	11,2%				
Pre-tax IRR - assets	%	4,0%				
Simple payback	yr	9,1				
Equity payback	yr	9,3				



Figure 50: Scenario 2 Cash Flow graphs showing cash inflows and outflows during investments lifetime

<u>Scenario 3</u>

Table 19: Scenario 3 Evaluated Financial Parameters

Financial parameters						
Inflation rate	%	1,50%				
Project life	yr	20				
Debt ratio	%	0%				
Total initial costs		•				
Capital Costs	€	240.000				
Annual costs and debt payments						
O&M (savings) costs	€	7.200				
Annual savings and income	•	·				
Electricity export income	€	33.679				
Total annual savings and income	€	33.679				
Financial viability						
Pre-tax IRR - assets	%	10,70%				
Simple payback	yr	9,1				
Equity payback	yr	8,4				





Figure 51: Scenario 3 Cash Flow graphs showing cash inflows and outflows during investments lifetime

As it can be identified by the above Figures, the IRR drops from 14,1% to 11,2% to 10,70%. The cumulative cash flow graphs from all scenarios indicate the Equity Payback which is the time in years when the outflows equal the inflows and thus NPV equals zero and the Simple Payback which follows the definition given in previous chapters.

From the three scenarios it is identified that the Simple Payback time equals 9,1 years, a calculation which if all site and turbine parameters are taken into account seems to be not in accordance to previous estimations. Nonetheless, Figure 44 presents a payback time equal to 5,6 years for a 50kW above 18 meters diameter turbine operating at 7m/s annual average wind speeds while in the calculation with RETScreen 4 a 14 meter diameter turbine is taken into account. Thus by considering the great effect of the over 4 meters in diameter on the annual energy yield, the difference in years can be justified.

The fastest in terms of reaching the outflow-inflow equilibrium investment is identified to be in Scenario 1 which also has the highest IRR equal to 14,1%. The identified Equity Payback, which represents the length of time that it takes for the owner of a project to recoup its own initial investment (equity) out of the project cash flows generated and considers project cash flows from its inception as well as the leverage (level of debt) of the project making it a better time indicator of the project merits than the simple payback (RETScreen 4, 2013), is equal to 7,1 years. Thus a difference from the Simple payback by almost two years is identified. Scenario 2 presents a smaller Equity Payback time and corresponding IRR undertaking values of 9.3 years and 11,2% respectively. Here the Simple Payback time is almost the same with the Equity Payback time indicating the less favorable terms of the undertaken loan which affects negatively the investment and the IRR. The fact that the acquired loan needs to be repaid in 15 years and not in the entire lifetime of the project significantly reduces Cumulative Cash flow since, as it can be observed by Figure 49 and Figure 50, the corresponding inflow at 15 years is approximately 125000€ to less than 100000€ for each graph accordingly. Finally in the case of the project funded by equity the corresponding IRR is equal to 10.7% indicating the worst investment scenario. Nonetheless the Equity Payback is equal to 8.4 years, over 8 months less than the Simple Payback time indicating a less favorable but still attractive investment. Also the Equity Payback is smaller than the previous Scenario but this is an effect of the previously acquired loan and its level of debt, which in this case does not exist. It must be mentioned that this scenario is the less likely to happen in reality especially regarding the economic problems of the country.

Finally it is interesting to note that in RAE's September 2013 report, large scale wind turbine investments Project IRRs (no loan is included (Feasibility.com, 2013) are estimated to be equal to 8%, 11.4% and 18.4% for capacity factors of 20%, 25% and 35% accordingly by taking into account an estimated capital cost of 1200 e/kW, annual O&M costs equal to 47 e/kW, expected lifetime of 20 years, average annual inflation equal to 1.5% and tax rates equal to 26% (RAE, 2013). If data are interpolated for CF 30% the corresponding Project IRR is estimated to be near 13,4%. If this IRR is compared to Scenario 3 where no lending is included, the economic potential superiority of large scale wind energy as inferred by chapter 2, can be confirmed. Nonetheless this fact certainly does not mean that small wind turbines not economically attractive in total but rather indicated that in order to compete with large scale technologies their implementation should be followed through under particular circumstances.

3.8 Comparison of SWT with prevailing small scale RET in Greece

Greece has an established market for RET implementation at urban level, mainly comprised of solar and biomass sytems but also expanding to sustainable building design and energy saving solutions. Analytically RET aiming for household implementation include:

- Photovoltaic systems
- Active/Passive Solar heating systems
- Biomass heating
- (Geothermal) Heat pumps
- Bioclimatic architectural design

The directly competitive, in terms of similarity to applications, implementation and end goal of operation, to small wind turbines and predominant RET in Greece regarding household (building-level) implementation is Photovoltaics. As presented in Figure 32, this technology has experienced unpreceded growth and currently more than 357 MW are installed in the country. Nonetheless because of issues regarding the funding of producers by LAGIE due to the very large number of the latter, overabundance of produced energy and very high guaranteed prices (further on the subject will be explained in the Financial Barrier Chapter), a decrease of Feed in Tariffs and suspension of the licensing procedures, have stemmed this rapid growth. During this sub chapter a direct comparison between Roof PV and SWT will take place on techno-economic terms.

The key differences identified between photovoltaics and small wind turbines can be categorized based on the manners of evaluating the primary renewable source potential, location of installation, calculation of power output, different part types per technology and required infrastructure, operation and maintenance requirements and economic parameters (Georgakopoulos A. , 2011).

More specifically on evaluating the source potential, regarding PV systems, accurate models exist which can calculate the annual energy yield by taking into account the geographical parameters of the installation in order to evaluate the solar irradiation and equivalent sun hours. The equivalent sun hours represent the equivalent amount of time in hours for which a PV panel experiences constantly a AM 1,5 Standard insolation equal to 1000W/m^2 (Woodbank Communications Ltd, 2005). Wind energy systems cannot only rely on the Weibull distribution if accurate calculations are to be performed and thus on site measurement data, which are in function with wind speeds, prevailing wind direction, landscape, obstacles which could introduce turbulences and interaction of neighboring turbines are required. The location of installation of PV requires the evaluation of the panel slope angle, their orientation to the sun and the effects of shadow areas which can reduce production substantially. These parameters can be accurately determined and quantified by on site measurements. In the case of SWT the effects of location parameters, such as obstacles affecting both the installation of the tower as well as induced turbulence, prove to be more difficult to evaluate or calculate. Also multiple PV panels do not affect the operation of one another whereas multiple wind turbines, if not installed with adequate spacing in between, can severely affect neighboring turbine operation by inducing turbulence in the free wind stream, thus reducing the energy yield. The calculation of PV power output is mainly a function of the installation area and panel peak power. In small wind turbines the power output is a function of blade type, rotor swept area, tower height,

generator type etc. It is evident that the characterization of a wind turbine's power output is affected by a larger number of parameters, thus constituting a much more complex task. While the options regarding the parts of PV systems are mainly limited to the panel, inverter and battery type, the options regarding small wind turbine systems are much more numerous, as it has been indicated by the technological analysis presented in Chapter 2. Among other parameters, the choice between Lift or Drag driven machine, orientation of the axis of rotation, type of control (active, passive), type of rotor, can provide with a variety of options which can be selected to best suit a specific site. Potential producers are required to have extensive knowledge over various aspects of energy production via wind harvesting and thus a selection of system is not as straightforward as in PV. Regarding the required infrastructure PV only require mounting equipment and no other constructions, contrary to small turbines which according to the place of installation (roof tops or ground) require far more foundation works. If SWT are installed on roof tops they may require similar mounting equipment but also sturdy bases which would introduce extra loads on the building. In the case of ground installed turbines, cement foundations and further construction works regarding the rising of the tower and stabilization of the turbine are required. The operation of PV is noise free, reliable, safe since it does not include moving parts and does not require frequent monitoring apart from scheduled maintenance for the cleaning of panels. Also PV operate only during daytime and produce less energy under cloudy conditions. SWT may produce unwanted noise levels, have higher safety requirements since they include fast rotating blades attached to the nacelle, and require specially trained personnel which can provide certified services regarding the installation and frequent maintenance of its parts. Nonetheless they can produce energy during the entire day as long as prevailing winds do not drop under the cut in speed. Finally there is a definite decreasing trend in the price of PV panels with an increase in efficiency due to the upgrading of materials, facts which do not hold for small turbines as well. The efficiency of the latter has remained at constant levels since no significant innovations in small wind turbine manufacturing have occurred and also prices range significantly between manufacturers with no decreasing trend identified. It should be noted that since PV present a much more mature technology, the economy of scale production has allowed for prices to drop. Small wind turbines are not yet on an equivalent level regarding production number and thus prices cannot be reduced in according manners.

In order to proceed with a comparison of economic model prices between the previously described regarding 50kW turbines and a power output equivalent PV system, the annual energy production per installed kW was required to be determined. By determining a kWh/kWp relation, an estimation for a 50kW PV system was made. Based on the Photovoltaic Geographical Information System (PVGIS) (European Commission , 2012) of the European Commission's Joint Research Center (JRC), the typical energy production per installed kWp was determined. The assumptions inserted in the tool where the following:

- Location: Athens
- Nominal power of the PV system: 10.0 kW (crystalline silicon)
- Estimated losses due to temperature and low irradiance: 10.5% (using local ambient temperature)
- Estimated loss due to angular reflectance effects: 2.4%
- Other losses (cables, inverter etc.): 10.0% Combined PV system losses: 21.4%

The result obtained was an annual energy production of 1600kWh per installed kW. Thus a realistic estimation of 80MWh is assumed for the following calculations, regarding a 50kW photovoltaic system. It must be noted that such a system does not consist a Roof installed photovoltaic but nevertheless represents a direct comparison to a 50kW turbine since neither the latter can be installed on a rooftop. If a typical Capital Cost of $2 \notin$ /Wp is taken then the total Capital Cost for a 50kWp system is equal to 100000 \notin . The feed in tariff of 125 \notin /MWh, as issued by 1 June 2013 for photovoltaics of installed power smaller than 100kWp (HMEPH Σ IA, 2013), is considered and O&M costs are assumed to be equal to 1% of the total initial investment (Lenardic, 2013). It is important to note that additional costs regarding batteries, inverters or other hardware are not considered. If these costs were included in the above calculations as well as their associated operation and maintenance costs all characteristic economic parameters would increase in value. By these assumptions the according Simple Payback Time and Cost of Energy can be approximated and presented in the following Table:

kwh/kw	Installed power (kW)	Total Annual produced Energy (MWh)	Total Cost(€)	Feed in Tariff (€)	Payback Time	Cost Of Energy (€/MWh)	Generation Cost (€/MWh)
1600	50	80	100000	125	10	200	75

Table 20: Payback Time and Cost of Energy for 50kWp Photovoltaic System

By comparing Table 20 with Figures 44, Figure 45 and Figure 46 it is evident that SWT can be directly competitive to photovoltaics only when operating at medium or above medium wind speed potentials. Nonetheless due to a much lower feed in tariff, the payback time regarding a 50kW photovoltaic is estimated to be more than that of a well sited equivalent wind energy system (if current prices are taken into account). Essentially photovoltaics are better suited for the Mediterranean climate of Greece especially regarding the mainland. In the islands small wind turbines may be competitive due to higher wind potentials but the intermittent nature of wind resources and operation of the turbine itself do not allow for a steady produced current. Thus connection issues may be a prohibiting factor for preferring SWT over PV implementation. Even in off grid applications in most cases PV are preferred to operate as the base energy production with turbines being complementary.

Despite the inferred superiority of PV in almost every aspect regarding implementation in Greece, the rapid growth of the first coupled with the covering of the national targets 2020 regarding PV technology already from 2013 and the decline of the governmental received support, as described in earlier chapters, may have had a positive effect on the relative cost effectiveness of SWT.

4 Barriers and Obstacles

In this chapter the barriers and obstacles which are limiting the development and implementation of small wind turbines on the built environment in Greece, will be identified. In order to proceed with the analysis, the framework proposed by J.P Painuly regarding barriers to renewable energy penetration, as published in Renewable Energy Journal, will be utilized. The chapter will begin with the utilization of the overall framework and the individual parts which comprise it, ever focusing on the Hellenic energy production regime characteristics. As such, each barrier category will be explored based in a top down level approach which will conclude to an in depth country specific analysis. Determined barriers listed in this chapter originate from literature study as well as interaction with stakeholders and namely HWEA, CRES, HEDNO and Hellenic companies in the field of supply, manufacturing and implantation of SWT which were contacted by the author. Especially in the case of companies, interviews and questionnaires have provided crucial insight regarding the perception of entrepreneurs on the difficulties faced by this technological branch which will be incorporated in each barrier category. Finally the chapter will conclude with the key bottlenecks for which proposed measures will be presented in Chapter 5.

4.1 Barrier categories identified by Hellenic companies

Before proceeding with the analysis of each barrier category, as identified and adapted by the analysis framework of J.P Painuly separately, it is worth presenting the results of communication with companies in the field of small wind turbines which provided valuable information regarding the most significant barriers perceived by them, as identified by the investigation conducted during this thesis (the details of which have been described in Chapter 3).

It was determined after interviewing company representatives that predominant barriers are perceived and prioritized differently according to the application types each business group targets and the immediate difficulties they impose. Thus companies which mainly focus on Off grid applications responded differently than ones focusing solely on On grid applications. Namely the first considered Technical Barriers to be of higher importance than Institutional Barriers since the constraints and obligations imposed by the according legislation for Off grid applications are only a fraction of the ones concerning small wind turbines for On grid applications. As identified by Figures 40 and 41 though, since most supplying companies provide all power output ranges of SWT the results of the inquiry converge into six (6) specific barrier categories. The results of this research are presented in Figure 52.



Figure 52: Barrier categories Percentages

As it can be determined by Figure 52 the most frequently identified barrier category is the one concerning institutional barriers. Almost 89% of Hellenic companies identified Institutional and namely legislation related issues to be the predominant barrier for the implementation of Small wind turbines. Although the legislative framework has been established and frequently amended by numerous laws and provisions, the opinion of companies can be fully justified by the sole reason that the most favorable FIT scheme and license issuance system provided by Law 3851/2010 was never implemented by the Hellenic stakeholders, leaving more than 950 On grid requests for connection on hold indefinitely. Second most frequent barrier categories were identified to be Technical and Market Failure/imperfections barriers. Mainly referred by Off grid applications orientated companies, technical issues (to be further analyzed in depth in the according sub chapter) were identified to significantly hinder the operation of SWT and prohibit potential investors from implementing such machinery, even in potentially favorable existing wind regimes. Market failure/imperfection barriers were also frequently mentioned mainly due to required missing infrastructure and lack of public information and awareness. Social related barriers were also referred by some companies especially regarding the implementation of SWT in large urban centers were aesthetics and acceptance of the technology are important parameters. Finally Market distortions as well as economic/financial barriers were not considered to be as high in priority as the rest. This presents a rather surprising fact but nonetheless in the general economic crisis climate of Greece which has already lasted 5 years and since the market targets Hellenic consumers, the economic difficulties are unfortunately considered as a given factor.

Regarding the specific barriers identified per each barrier category the following Table presents the results of the Hellenic company inquiry. As mentioned previously the Institutional related barriers are considered to be the most significant for Hellenic companies and mainly the lack of implementation of regulations and still complicated and time consuming licensing procedures. Also highly important were the lack of communication between stakeholders especially between Government Institutions and companies and the claim of the latter concerning the diminishing support of the Ministry of Environment, Energy and Climate Change towards RES. It is worth noting that the majority of companies (although they did not

mention) acknowledged the fact that the current economic crisis has essentially "crippled" the efforts of consumers to invest to household-size RET since they consider such attempts as risk associated.

Barrier Category	Barriers	Barrier Elements
Institutional	Problems in realizing financial incentives, Lack of involvment of stakeholders in decision making, Clash of Interests	Legislation issues, lack of implementation of regulations, complicated licensing procedures, lack of adequate communication and mistrust between RET stakeholders
Technical	Lack of Standards, Codes, Certifications and trained personel, System Constraints, Unreliable Products	Installation, maintenance, vibration, noise, Network/System integration problems, inadequate urban planning, lack of trustworthy wind potential measurements
Market Failure/implerfections	Poor market infrastructure, High transaction costs	Mismanaged Energy Sector, Delay of Procedures
Social	Lack of social and consumer acceptance	Aesthetic considerations, NIMBY (Not In My Backyard) Syndrome, resistance to change
Market Distortions	Favorable treatment to conventional energy production methods	Shift of attention to natural gas imports
Economic and Financial	High upfront capital costs for investors, Lack of consumer access to credit	High efficiency related costs, unsafe economic environment for investments, inadequate incentives

Table 21: Identified Barriers by Hellenic Small Wind Turbine Companies

4.2 Analysis per Barrier Category

4.2.1 Technical

Small wind turbines present complications which are not identified in Large scale farms. The nature of this technology and its implementation near or in populated areas immediately generate technical related issues which are required to be minimized. Regarding the technical barriers of SWT a distinction can be made between the obstacles imposed by the technology itself and by externally related parameters. As such noise generation, shadow flickering, difficulties in rotor orientation and control, failure and breakdowns are among obstacles which can be included in the first category whereas lack of certified and qualified installation personnel, lack of standardized procedures and System constraints can be included in the second category.

One of the most predominant technology related issues posing a technical barrier (which generates also social barriers) is *noise emissions* (Gipe, 2004; Syngellakis, 2006). The noise produced by small turbines is unavoidable and despite the technological progress "silent" SWT have not yet been manufactured. Despite that fact the parameters which cause noise generation have been identified and successful efforts have been conducted towards their decrease.

Wind turbine noise is mainly a cause of two distinct parameters: the effects of the interaction of the blades with the air stream causing the so-called *Aerodynamic noise* and the effects of the electro-mechanical

equipment located inside the nacelle or orientation (turning) of the turbine causing the so-called *Mechanical noise* (Burton , Sharpe, Jenkins, & Bossanyi, 2001).

The Aerodynamic noise constitutes of the following parameters (Burton , Sharpe, Jenkins, & Bossanyi, 2001):

- Low Frequency noise
- Inflow Turbulence noise
- Airfoil Self noise

The first type of noise is mainly observed with downwind turbines while it is not restricted to them only. The cause of low frequency noise is the change in wind velocity due to the wind shear effect. Although this noise type is more predominant at Large scale turbines for which the effect of the tower shade and wind shear are more accentuated, the upper limit of small turbines maybe produce such noise as well. Inflow turbulent noise is created by the interaction of the blades with turbulent air streams. They are the main reason from the characteristic "Swishing" noise produced by turbines and are in function with the blade velocity, airfoil section and turbulence intensity of the air stream. It follows that obstacles in front of SWT which create turbulent wind profiles, as explained in chapter 2, increase such noise levels. The airfoil self-noise exists even in turbulent free air streams and is generated by the airfoil itself. A number of types of airfoil self-noise exist with the most important being the trailing edge noise, tip noise, stall effects and surface imperfections (Burton , Sharpe, Jenkins, & Bossanyi, 2001). The thickness and shape of the trailing edge as well as the blade surface can affect significantly noise emissions since they affect the aerodynamic interaction of the blade with the air stream.

According to various researchers, such as Paul Gipe, the aerodynamic noise can be summarized as being principally a function of blade tip speed ratio (λ) and shape. As stated in Wind Energy Handbook, the aerodynamic noise generated by a wind turbine is approximately proportional to the fifth power of the tip speed. By considering the relation of tip speed, solidity and hence number of blades and the power coefficient the difficult compromise between noise emissions and higher power production is evident. As stated in Chapter 2 turbines which have lower solidities and hence less blades can operate at higher tip speed ratios and thus are preferred for electricity production. Nonetheless the obvious approach in reducing aerodynamic noise is reducing the tip speed which will result in a loss of extracted energy. The control of a turbine can further reduce or increase this effect. In fixed/constant speed turbines the tip speed is fixed and thus the peak efficiency is reached only at one particular wind speed corresponding to that tip speed ratio. In all other velocities the turbine does not operate optimally and due to the fixed λ , it produces noise which can be distinguished at low wind speeds where ambient noise is also low. Also at high wind speeds the blades will stall thus cause vortex shedding which will induces velocity and hence pressure differences, causing noise (Burton, Sharpe, Jenkins, & Bossanyi, 2001) (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004) (Mertens, Wind Energy in the Built Environment, 2005). This is not the case with variable or two speed turbines where the these types of control can allow for the regulation of tip speed which has a dramatic effect (since noise is a function of λ^5) on noise emissions (Burton , Sharpe, Jenkins, & Bossanyi, 2001).

Apart from the effect of solidity/tip speed ratio on noise, the number of blades, even if all other parameters are considered fixed, can have an effect. As defined by NREL Laboratories, two bladed turbines produce greater noise than three bladed turbines since the first place higher loads on each blade for an equivalent output (Gipe, 2004). Also the diameter of blades affects noise with the larger the diameter being the greater the noise emissions. Nonetheless small turbines relative to their rotor diameters can be considered noisier than large ones (Gipe, 2004). If the sound power is taken into consideration, defined as L_w with decibel of the A scale focusing on audible frequencies (dBA) units, the following Table describes the above notion:

Turbine	Rotor Diameter (m)	Rated Power (kW)	Sound Power	
			@ 8 m/s	@ 10 m/s
Whisper H40	2,13	0,9	85	-
Calorius	5	4,6	82	-
Gaia	7	$6,\!5$	88	-
Genvind	13	23,7	103	-
Furlander	13	30	93	-
Enercon E30	30	200	95	99
Nordex N43	43	600	101	-
NEG-Micon	60	1000	98	101

Table 22: Comparison of Small to Medium wind turbines noise emission as a function of rotor diameter and rated power (Gipe, 2004)

Worth noting is the fact regarding the relation of aerodynamic noise with the turbine rotor axis of orientation. As identified by numerous researchers, Vertical axis wind turbines are "quieter" than their Horizontal axis counterparts since they usually nominally operate at tip speed ratios which are half the tip speed ratio of the latter (Eriksson, Bernhoff, & Leijon, 2008).. Furthermore VAWT can incorporate swept or canted blades which can further decrease noise emissions (Mertens, 2005)

Mechanical noise originates from the motion of mechanical parts and friction between them. Such parts include the gearbox and yaw mechanisms, the noise of which can be amplified by the hub, rotor and tower (Rogers, Manwell, & Wright, 2006). The electrical equipment can be a source of noise as well as the generator and other auxiliary parts such as hydraulics or cooling fans. Individual noise sources can contribute to the overall Mechanical noise, which can follow a structure -borne path rather than an air borne path (followed by aerodynamic noise). Figure 53 presents typical noise sources of according sound power (dBA) which can provide characteristic values in order to grasp the magnitude of different component noise generation levels.



Figure 53: Sources of mechanical noise transmitted by structrure paths (Rogers, Manwell, & Wright, 2006)

It should be noted that small wind turbines which have adopted the direct drive design can avoid sound sources such as the gearbox, thus reducing the generated noise significantly.

Shadow flicker is defined as the stroboscopic effect of the shadows cast by rotating blades of wind turbines when the sun is behind them (Burton, Sharpe, Jenkins, & Bossanyi, 2001). The rapid moving casted shadow of the blades at frequencies between 2,5-20 Hz may cause disturbances to people indoors when lighting is provided by narrow windows. This effect is most prominent to medium size turbines rather than small wind turbines since the latter do not possess long enough blades to cast such shadows and operate at higher tip speeds. Also regarding Greece shadow flickering would not be considered such an important issue since it is more of a nuisance in higher latitude winters (Gipe, Wind Power: Renewable Energy for Home, Farm, and Business, 2004). This technology barrier can be significantly reduced or avoided if proper care is taken regarding the siting of the turbine and the antireflection coating of the blades.

Vibrations caused to supporting infrastructure is another technology related issue which can pose a barrier of high significance to small wind turbines and especially to those mounted on roof tops. Literature indicated that vibrations are in function with the rotational frequencies of the rotor, the number of blades, the blade mass unbalance and aerodynamic loading difference which are all linked via the *rotational sampling* phenomenon. Rotational sampling occurs when the blades moving through turbulent air which obtains different than the average velocities, induce vibrations. More analytically the vibration frequencies caused by a Horizontal axis wind turbine are equal to $n_{\rm H}$ which is the rotational frequency of the rotor and iBn_H which is the rotational sampling frequencies, with i being an integer corresponding to different velocity regions crossed by the blades and B being the number of blades. Regarding Vertical axis wind turbines, the same vibration causes are identified with a difference being identified at rotational sampling induced frequencies which are twice as high of HAWT ones due to the inherently different aerodynamic operation and interaction with the wind streams of the first (Mertens, 2005). It follows that transferred vibrations to a building rooftop may present structural hazard and induce unwanted noise. In both cases measures such

as strengthening of the building or use of dampeners, are required which may increase upfront installation costs and reduce acceptance and deployment (Smith, Forsyth, Sinclair, & Oter, 2012). The lack of control strategies to reduce vibration and noise due to the highly turbulent and varying direction wind resources in the urban environment needs to be addressed by the industry through standardized testing procedures which currently do not exist internationally.

Other technology related issues include Fatigue resistance, braking redundancy, lack of fail-safe features, control of yaw rates and avoidance of resonance frequencies (Smith, Forsyth, Sinclair, & Oter, 2012). These issues although addressed by the manufacturing industry may still be the cause of significant and potentially hazardous malfunctions which in the long run may be the cause for a diminished market penetration. Important is the fact that design and test standards for SWT in high-fatigue environments do not exist (Smith, Forsyth, Sinclair, & Oter, 2012).

Of major importance for the adoption of a novel technology, is the establishment of consumer trust towards a particular product both in terms of expected benefit yield and also reliability of sound design, installation, operation and maintenance. In order for SWT to be accepted as worth implementing and safe technological products and in order to firmly address all previously mentioned barriers, such assurances must be provided by according authorities which can validate that specific requirements for all different aforementioned aspects are followed. Thus the existence and implementation of internationally and country accepted Standards, Certifications and Quality assurance Codes is of the outmost importance.

The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising of all national electrotechnical committees (IEC National Comities) that has issued a number of standardization protocols regarding all aspects of small wind turbines. Currently the IEC 61400-2 International Standard regarding the Design requirements for small wind turbines is the most renounced standard which aims to replace the various national standards, forming a basis for global certification. This particular IEC standard deals with safety philosophy and engineering integrity throughout all phases of small wind turbine design, manufacturing and implementation. Also the IEC 61400-11 standard exists which deals with turbine sound power measurements and defines the manner in which such measurements must be conducted in order for the final product's sound power levels to be valid. As discussed previously the permitted sound levels are then defined by each country or legislation framework, but obtaining the IEC certification ensures that sound power levels presented by the manufacturer are accurate. In many countries and mainly in the largest markets such as the US and UK, national or other private organization standards exist which are used together with IEC or even can substitute the latter. For example standards have been issued by the American and British Wind energy Associations as well as the Japanese Small Wind Turbine Association, such as the AEWA 9.1-2009, the BWEA Small Wind Turbine Performance and Safety Standard and the JSWTA Standard which take into account the particular market characteristics and national requirements regarding the manufacturing and use of micro generation machines while incorporating parts of the IEC 61400 Standards with exceptions or modifications. Such modifications may also impose limitations regarding the connection to the grid or construction works which essentially help in the further custom-country standardization of procedures. Furthermore many countries have adopted schemes, such as the British Microgeneration Certification Scheme (MSC) scheme, designed to evaluate according products and installers against criteria in order to provide greater protection for consumers (Small Wind Certification Council, 2013).

Unfortunately the 61400-2 and 61400-11 are not endorsed by the majority of small turbine manufacturers and also have a number of gaps and Challenges which further hinders their adoption. More specifically the IEC 61400-2 standard has been composed with regard to HAWT with the technical description taking into account a generic HAWT design, thus presenting significant difficulties for VAWT manufactures to abide by it (Jain, Hewitt, Spossey, & Hudon, 2013). Also the standard requires a number of calculations which may be difficult in terms of time to be conducted especially by relatively new or emerging companies. The economic factors are also prohibiting for the majority of manufacturers since obtaining the certification can be an overly costly procedure (Hellenic Wind Energy Association, 2012). The IEC 61400-11 may not be adequate for the calculation of sound levels for all wind turbines since it requires the measured wind speeds to be equal to 6-10 m/s whereas a broader range must be used (Rogers, Manwell, & Wright, 2006). Also national standards may not be accepted in different than the issued country. It follows that a turbine which has been certified for use in the UK may be dangerous to implement in another country due to differences in climate conditions, landscape, building planning and construction. Nonetheless it should be noted that in Germany which is a leading country in the implementation of such technologies, both the AEWA 9.1-2009, the BWEA standards have been adopted but not the IEC 6400-2 standard due to aforementioned high costs (Hellenic Wind Energy Association, 2012).

A significant underdevelopment is identified regarding the adoption or the initiative to create standards in the Hellenic market but this can be attributed to the fact that the supplied wind turbines are nearly entirely imported by foreign companies which are free to choose whether to abide by a specific Standard or not to abide to any at all. A global problem deriving from the lack of an internationally adopted standard (which affects both the credibility of the technology implementation technically as well as economically) is the fact that no universally accepted manufacturing standard test conditions, to which the different parts of a small turbine can refer, exists. The conditions (rated wind speed) for which the rated power of a machine is defined, are chosen by the manufacturer thus introducing several uncertainties. Practically this means that a wind turbine manufacturer can claim lower rated wind speeds making the characterization of rated operation subjective. This fact can be verified by the large variation in the rated wind speed value which means that the specific parameters related to rated power cannot be compared directly, as they do not refer to the same conditions (European Wind Energy Association, 2009). Thus the Hellenic market cannot control turbine quality at a design and manufacturing level but can only rely on the initiative of companies to create products based on such Standards.

Since Greece cannot impose or control company manufacturing standards and since no domestic industrial facilities for production of such products exist where such standards could be imposed, the reasonable manner to perform quality control would be the issuance of certificates for imported small wind turbines, which would be evaluated on whether they fulfill specified National Criteria after being tested at specific facilities or Test sites, in order to be permitted to enter the Hellenic market. Nonetheless, contrary to other European countries, a severe lack of adopted international or created national certification criteria or quality control schemes such as the aforementioned MSC scheme unfortunately is identified. Also Test sites or facilities are few and do not serve for the above mentioned goal. Currently no Hellenic institution based criteria exist and no initiative has been taken for the creation of such criteria which could provide the basis for the evaluation of small wind turbines and granting of permission for their implementation and installation. Thus no quality control can be either imposed in this manner as well. For the above reasons
products of lesser quality can enter the Hellenic market which inevitably will result in a significant number of failures and break down or heightened periodic induced maintenance costs which will eventually establish the perception that SWT are synonymous to commercially high risk investments.

Another standardization/certification related issue is the lack of certified personnel which has undergone specific training in order to ensure safe, reliable and correct turbine installation and maintenance. The installation and service of a SWT is a potentially hazardous task if inexperienced and poorly trained personnel is employed. In the past a number of fatal accidents due to human error (which could have been avoided) has occurred when safety rules were not followed or "bent" (Gipe, 2004). The confined space in the case of a building implemented turbine, the significant height of the tower of a ground installed turbine and the spinning of the rotor in both cases are all factor which if not taken under serious account may lead to accidents. It follows that a catastrophic failure which could be the cause of such an accident could tarnish the image of urban wind energy irreversibly. Also not certified installers may perform a poor job during the assembly and installation and thus apart from the case of accidents may significantly reduce the efficiency of operation resulting in a negative perception of the technology as inherently inefficient. It must be noted that such installation safety related barriers apply to almost all technological projects but in the particular case of SWT, the proximity of inhabited areas renders them of the highest importance.

In Greece a significant deviation is observed in the quality of wind measurements. This fact presents a significant barrier which may be the cause of further damage to the reliability of the branch. The only source of wind velocity measurements is CRES, which has issued wind potential maps that though may not fully translate into the built environment. As stated in WWEA 2013 report, traditional wind resources maps may prove inadequate because wind conditions are often evaluated at greater than 50 meters altitude whereas most SWT do not surpass 30 meters of height. Thus in the case of detailed annual measurements the investor or consumer has no choice but to rely to the credibility of the wind turbine supplier which most often performs the velocity study. Nonetheless their detailed field measurements importance to a successful investment is crucial. Since there has been no adopted Hellenic scheme or other institutional directive regarding the way wind measurements should be conducted, despite the fact that Article 13(2) of Directive 2009/28/EC states that the wind measurements on site need to be carried out by certified bodies, in accordance with standard DIN-EN ISO/IEC17025/2000 (Ministry of Environment, Energy & Climate Change, 2010), it is impossible to control and guarantee whether the effects of turbulence from nearby obstacles and other parameters are properly quantified and taken into account to produce quality measurements. It should be noted though that the challenge of understanding and quantifying the wind resource in the urban environment is global since there is a lack of measurements and model results which could assist in the development of an international standard/guideline currently lacking from IEC 61400-2 (Smith, Forsyth, Sinclair, & Oter, 2012).

The particular environment characteristics of Greece impose additional technical barriers which induce difficulties in the implementation of these machines. Specifically the main environmental parameters which are identified are:

- Marine environment (corrosion)
- Earthquakes

- High Solar radiation and temperatures
- Rain, hail, snow and ice

The coastal areas of Greece have higher humidity and salinity levels and thus may accelerate corrosion of any unprotected metal parts which may hinder the structural integrity of a roof base or ground infrastructure. Due to frequent earthquakes towers, supporting parts and ground foundations are also required to be able to withstand vibrations and to be guaranteed that they will not fail catastrophically. The erection of machines which can reach heights over 20 meters under such conditions may prevent investors from installing turbines. The climatic conditions mentioned above may also create structural hazards, reduced energy production (especially frost on the blades) or increase the O&M costs significantly.

Hellenic cities and urban centers in general are not comprised of high altitude buildings in rows. In fact Greece is one of the few EU countries where skyscrapers have not been built and the highest building is only 103 meters tall (Emporis, 2013). Although low story buildings are disadvantageous for the implementation of SWT the highly mountainous geography of Greece compensates for implementation of small wind turbines at high altitude urban centers. Nonetheless low building height pose a technical barrier for SWT implementation since surrounding obstacles will greatly affect the wind profile and introduce turbulence which will eventually decrease the expected energy yield.

Finally system constraints and limitations of the grid System or Network have also imposed difficulties which contrary to large scale wind energy are significantly less due to smaller power capacities. As such further infrastructures (sub stations, power lines) are usually not required. In the case of Off grid systems no such problems are considered.

4.2.2 Institutional – Legal

Although Greece is in accordance to the EU directives regarding its RET related legislative and regulatory framework, the severe inability of both governmental institutions and companies to follow or impose the existing regulations and laws due to ineffectiveness of the latter, external constraints and most importantly due to mismanagement of the Sustainable energy sector (Market Failure/Imperfections) has posed a serious barrier for the implementation of small wind turbines in the country. As defined previously, the majority of Hellenic Companies interviewed consider Institutional related problem to be the most important barrier for the expansion of this technology. Also the technical barriers stated previously, related to the lack of a system of standardization, certification and evaluation of wind turbines, installation procedures and wind potentials which ensures quality control are linked or originate from the ineffectiveness or missing parts of existing regulations and laws. It is worth noticing that the National Hellenic Renewable Energy Action Plan mentions that no national or regional legislation concerning certification or equivalent certification scheme for installers or body for setting up and authorizing such schemes according to Article 14(3) of Directive 2009/29/EC exists (Ministry of Environment, Energy & Climate Change, 2010). To avoid repetition these barriers will not be referred in this chapter as well.

Painuly's framework includes the institutional barrier of Lack of a legal/regulatory framework and the barrier of problems in realizing financial incentives (Painuly, 2001). Although the second barrier which is attributed to complicated procedures can be easily identified for the case of Greece, as it has been presented

by previous chapters, a legal/regulatory framework exists in country. Nonetheless if the particular barrier is further analyzed, the following barrier elements (level 3) can be associated with the case of SWT in Greece:

- Missing or ineffective regulatory body
- Regulations inadequate to promote RETs
- Lack of implementation of regulations

The main regulatory bodies of Greece are the Ministry of Environment, Energy and Climate Change (MEECC) and the Regulatory Authority for Energy (RAE). The first is essentially responsible for the creation of legislation while the second is responsible for the supervision of the market and according regulations (having significantly less authorities than MEECC). Both bodies are though equally responsible for the promotion of this technology in the country though the fulfillment of their according obligations. By introducing in 2010 the most favorable but still complicated law 3851/2010 both bodies showed the willingness of the Hellenic government to promote the technology of small wind turbines. Unfortunately more than three years later the disappointing result of almost no On grid installed SWT and over 160 million euros worth of investments put on hold (Miniwind ltd, 2012) has been identified which (if the lack of willingness is overruled) can be attributed, among other factors, to the above mentioned barrier elements.

More specifically although law 3851/2010 guaranteed the FIT of $250 \notin$ /MWh and provided several exemptions to accelerate procedures for smaller than 20kW nominal power machines it still did not manage to simplify enough the licensing system of the country or correct bureaucratic constraints which would decrease the time frames for both RES licensing and grid infrastructure works (Ministry of Environment, Energy & Climate Change, 2010). As a matter of fact in the Greek National Renewable Energy Plan it is stated clearly that "the regulatory and legislation environment is extremely bureaucratic thus restraining the sustainable development of RES in the country" (Ministry of Environment, Energy & Climate Change, 2010). As expressed by some Hellenic companies, the licensing procedure required as much time and requested documents as almost the ones required for large scale projects. Furthermore in order for a project to be finalized and a wind turbine to be connected to the Network the law states that a financial agreement between the producer and the Operator of the Network (HEDNO) or PPC which is the owner of the Network is required.

Regarding the conclusion of this financial agreement more than 4 stages of licensing procedures were identified to be required: Connection Request, Binding Connection Request, Connection Contract and Energy Sales Contract (Hellenic Wind Energy Association, 2012). By observing the data provided by HEDNO regarding the more than 958 connection requests it is observed that nearly none of them has passed through the very first stage. Although the regulations were clear and the number of requests had already reached a significant number in the time period 2010-2011 the MEECC primarily and RAE secondarily did not apply any pressure for the finalization of these requests by HEDNO/PPC (M $\alpha\theta\iota\sigma\sigma\upsilon\lambda\sigma\varsigma$, 2012). Thus due to the significant bureaucratic difficulties and inability of MEECC and its advisory body (RAE) to implement law 3851/2010 or obligate the Network operator to consider all pending applications, a significant and catastrophic delay was created with a large number of producers eventually proceeding to the cancelation of their request. After the recent creation of the financial deficit of LAGIE (explained in the Economic and Financial Barrier sub chapter), which is the institution responsible for the

economic promotion of RES through the Feed in Tariff issued system all requests were further put on hold under the justification of preventing a small wind turbine market "bubble" equivalent to the Photovoltaic Hellenic Market one. Thus effectively the small wind turbine market concerning On grid turbines in Greece has been put on hold from 2010, thus granting according regulations as inadequate.

Also the existing legislation and regulations have failed to address the specific urban planning issues and physical planning deficiencies related to this technology (Ministry of Environment, Energy & Climate Change, 2010). Urban Development and Regional planning rules have not been clearly addressed by the Hellenic government leaving room for misinterpretation and potentially hazardous installations. More specifically the legal document concerning such issues (presented in OG 2464 B/03.12.2008) does not take into account small turbines but only machines with 85 meters of rotor diameter. The fact that this document has not been revised or a separate urban development plan has not been issued for specifically SWT which will incorporate previous mentioned standardizations is evidence of the inadequate regulations regarding this technology.

Another significant issue is the frequent change of laws and regulations. As identified by the according chapter the regulations concerning RES have already undergone more than three major legislative changes and a substantial number of reforms and amendments leading to a highly promoting law which unfortunately has never been implemented for this particular technology. Also today a new law is being considered by the Hellenic parliament which will completely change previous policies regarding small scale RET reaching as far as abolishing the FIT system and introducing Net-metering for household producers among other changes. This policy instability has posed a barrier to investors since it has led to confusion, mistrust and a perception of risk associated with the implementation of this technology. It follows that a potential investor will most likely not choose to proceed with the purchase or installation of a turbine when the rules of the market and state are to change after five years or less, especially when the investment has a long payback time.

The frequent policy changes up until 2010 were attributed to Greece's efforts to harmonize its legislative framework to the EU according directives. Further changes though may be also attributed to the current economic crisis and the efforts of the government to conform to the signed Memorandums between the first and the European Commission, the ECB and the IMF. Both the First and Second Memorandum of Understanding on Specific Economic Policy Conditionality signed in the 6th of May 2010 and the 13th of February 2012 by the Hellenic Parliament include specific proposed measures and suggestions for the promotion of Renewable Energy and reform of the Hellenic Energy market in total. The suggestions although sound in nature focused more on the liberalization of the Energy sector and the reform of the RES market in order to fulfill the country's EU obligations but also to reduce government related expenditures. Also special care was given to the promotion of project 'Helios' and the implementation of photovoltaics (Directorate General for Economic and Fiancial Affairs, 2011; Directorate-General for Economic and Fiancial Affairs, 2013).

In the paper published by the European Commission following the last visit of the Troika between 4-19 June and 1-7 July 2013 (Second Economic Adjustment Programme for Greece-Third review) the goal of the government to make the RES sector competitive and to allow it to contribute to Greece's growth is described as being directly linked with the effort to reduce the balance sheet of LAGIE (Directorate-General for Economic and Financial Affairs, 2013). Reduction of FIT, adjustment of the RES levy paid by consumers every six months and other proposed measures although beneficiary for the deficit of LAGIE are essentially limiting the implementation of RES, especially the ones which require strong incentives for their promotion. The proposed measures may eventually lead towards the correct or most viable direction of establishing such technologies in Greece, but do not separately address different RET but rather focus solely on the economic stability of institutions. This different debt covering-oriented approach does not ensure the correction of wrong doings for the implementation of small wind turbines, the future of which is left to be decided by the new proposed legal act "Regulation of Renewable Energy Sources (RES) matters and other provisions".

Table 23: Proposed Measures included in First and Second signed Memorandum between the Hellenic Government and European Commission, the ECB and the IMF (Directorate-General for Economic and Financial Affairs, 2013)

	~	•		
First Energy Sector	Second			
	Energy Sector	Renewables		
Finalization of plans for the liberalization of the wholesale electricity market and commence with the rationalization of consumer tariffs	1st Quarter 2012: Government finalises the remedies to ensure the access of third-parties to lignite- fired electricity generation	1st Quarter 2012: The Government completes the transposition and the implementation of the renewable energy Directive (2009/28/EC) and submits the progress report required by the Directive		
Adoption of legislation to unbundle electricity and gas activities, including measures	2nd Quarter 2012: Government starts implementing the measures ensuring the access by third parties to lignite-fired electricity generation	Government prepares a plan for the reform of the renewable energy support schemes such that they are more compatible with market developments and reduce pressures on public finances. This plan should include		
Adoption of measures to strengthen the independence and capacity of the Energy Regulatory Authority	November 2013: Implementation of the measures to ensure access by competitors of PPC to lignite-fired electricity generation is completed. Third parties can effectively use lignite-fired generation in the Greek market June 2013: Further measures are adopted to ensure that the energy component of regulated tariffs for households and small enterprises reflects wholesale market prices, except for vulnerable consumers	 A timetable scheduling meetings and stakeholder discussions on the reform of the support scheme Options for reform of the support scheme, including a feed in premium model, and specifying in each option the method of tariff calculation and the means of avoiding possible over compensation Current and expected trends in costs for all relevant technologies Consideration of the option of automatic tariff digression Measures for the development of wind and solar energy resources 		
		Government pursues implementation of the renewable energy project 'Helios,' through legislation (1st Quarter 2012), facilitation of licencing process (2ns Quarter 2012) and cooperation with other EU countries for the export of solar energy		

Further regarding the Hellenic crisis, the over three year unstable macroeconomic environment in the country, which could not be addressed or countered by according regulations regarding the implementation of RES, has posed a barrier to SWT investments. Since early 2010 Greece has requested the aid of the Eurozone countries, International Monetary Fund in the form of loans (which were provide under conditions and harsh austerity measures), has endured social uproar and has been on the verge of declaring default and exiting the Eurozone- the so-called "Grexit". Although the small internal market of small wind turbines had been unofficially already put on hold by the inability of the according operator to proceed with

the licensing procedures by early 2011, the unstable policies, balance of payment problems experienced by other RES producers and uncertain economic growth further decreased investment interest and activity having a devastating effect both on related companies and the maturity of the market as a whole.

The inability of according stakeholders and specifically of MEECC to promote this technology, despite the fact that in 2010 the foundations for its establishment had been set by the according law, may be an indication of clash of interest related barriers. More specifically when RES are competing with conventional energy methods which have been established, the penetration of the first may be undermined by the second. The existence of RES may pose a threat to the utility dominance and hence to acquired profit from conventional energy methods. Powerful conventional energy lobbies may thus hinder the implementation of RES by affecting the decision making of other stakeholders and the implementation of regulations. As a matter of fact two company spokesmen interviewed for this thesis mentioned that the unwillingness of according government stakeholders to press for the implementation of SWT reached the level of "sabotage" to small wind turbines. The dominance of PPC lignite mines and the efforts of the Troika to further liberate the energy market but at the same time reducing FIT and not addressing the pending issue of lack of regulation implementation could indicate such a situation. Also when different RES technologies compete with each other, more powerful or active lobbies may promote one technology over another. The overabundance of photovoltaics and the fact that the 2020 National energy goal for PV produced energy has been reached by 2013 (if rooftop PV are also included) (RAE, 2013) while almost no small turbines have been installed online, may also strengthen the above argument. It must be noted that a potential existence of a clash of interest and its related consequences on small wind turbines is not possible to be confirmed and goes beyond the scope of this thesis. Thus the above mentioned information are considered to be speculations and personal opinions.

Institutional barriers included in the framework of Painuly which are linked together are the lack of professional institutions, lack of R&D culture and lack of involvement of stakeholders in decision making. The Hellenic market branch of Small wind turbines is characterized by the absence of professional associations such as the ones existing for the photovoltaic sector (Hellenic association of photovoltaic companies, Hellenic association of photovoltaic investors, Association of photovoltaic energy producers) with the Hellenic Wind Energy Association being the sole representative of it. The lack of manufacturers and underestimation of the role of R&D in the adaptation of the technology to the Hellenic physical and economic environment also contribute to the nonexistence of associations consisted of related companies or investors which could further the efforts for the establishment of SWT.

Contrary to the large scale wind energy manufacturing industry which requires infrastructure and funding for research currently impossible or economically not attractive to be provided by Hellenic stakeholders, small scale turbines (requiring substantially less funding) R&D facilities, which would significantly increase the growth of this technology, can be established. Unfortunately, as described previously, almost all turbines are imported and thus no research is performed. Company R&D facilities do not exist and any research conducted in the country is performed solely by CRES or universities. The above facts in turn create a severe lack of participation of stakeholders in decision making. Apart from the efforts of HWEA, which also promotes the interests of the Large scale wind energy industry, no other consulting institution can apply pressure to the government in order for the industry to mature and expand. Also the sole efforts of individual companies unfortunately have not yielded results and opinions which could solve significant market problems have not been taken into serious account.

4.2.3 Economical – Financial

Although not highly prioritized by Hellenic companies, economic related issues introduce very significant barriers to the implementation of this technology. It can be understood that the "downgrading" of high capital and maintenance costs from companies can be attributed to the efforts of the latter to promote the technology but despite marketing attempts this issues still pose a major consumer barrier especially when competing technologies offer more short-term economically advantageous solutions with lower upfront costs. Also apart from high market prices, the economic crisis environment creates difficulties to consumers regarding funding, which even if provided in the form of loaning, is perceived as a high risk endeavor. Such economic barriers will be addressed in this sub chapter in an effort to clarify why this technology still lags behind other RET in the economic environment of Greece.

As identified in Chapters 2 and 3, the implementation of (urban) wind turbines represents capitalintensive investments. The more detailed analysis presented in Chapter 3 though has indicated that if adequate incentives are provided, such as FIT or other promoting systems, such investments can be profitable in the long run. Nonetheless SWT as final products still face economic viability barriers which originate from high upfront costs, underestimation of other remaining costs and problematic resource evaluation which overall render them costly for the average user.

According turn-key projects (thus including the purchase of the turbine but also all other related expenditures as stated in Chapter 2) reach price ranges of $2500-5000 \notin$ kW or even more if annual wind measurements are included which may cost between $2500 \notin$ and $6000 \notin$ according to the certification (if available) and method each individual company possesses. It can be easily identified that the cost of wind measurements is high relative to the cost of the wind turbine and can increase upfront costs by over 40% (considering the implantation of a few kW turbine). Also the costs for connecting to the grid and acquiring all necessary licenses are also high, relative to the cost of the turbine itself (here presenting data for a 50kW on grid turbine) reaching according percentages from 11,7% to 37,5% and percentages equal to 8,3% to 24% relative to total investment costs (Georgakopoulos T. , 2011). It is evident that the presented higher range percentage values contribute significantly to the upfront costs.

As shown in Chapter 3, the direct market competitive technology of photovoltaics have upfront costs which are equal to $2000 \notin/kW$ if extra costs (installation, O&M) are added and thus can be perceived as economic more attractive products. Regarding the high capital costs of SWT as compared to PV, it should be noted though that the latter have been established in the RES market of Greece for years and are produced and imported in numbers thus essentially having achieved a reduction of upfront costs from $6 \notin/kW$ in 2009 to $1,7 \notin/kW$ in 2013 ($\Lambda i \alpha \gamma \gamma \sigma v$, 2013). Also market prices in relation to production costs have reach a level of stability while small wind turbines are still in the development stage or price umbrella stage where an established technological product does not exist and both production costs and market prices remain high and do not follow the same trend. To express the above statement graphically, the following Figure is introduced which represents the relation of market price and costs during the market introduction of a new product:



Figure 54: Product Price versus production cost as a function of the cumulative output (Madlener, 2012)

Although SWT have progressed technologically and as described in chapter 3 have begun to globally expand in implementation, the small Hellenic Market demand and sales volume, the high technology deviation leading to price deviation and the overall immaturity of the market have not allowed for the linearization of market prices as related to costs. The PV market is currently on the last stage of Stability where prices and costs move downwards in parallel. If small turbines are to grow in the RES market such a relation needs to be established.

Also of high importance is the lack of rationalization of prices with regard to efficiency of the product since currently the existing high capital costs of SWT do not necessarily reflect the latter parameter, especially when compared to other technologies (RES or conventional) but also when compared to different turbine types. Practically this can be translated into the fact that the purchase of solely a wind turbine which optimally produces 1kW of power operating with a specific efficiency may be more costly than the purchase of an equivalent system of different technology. Furthermore, since small wind turbines define a broad range of machines which produce power, ranging from hundreds of Watt to fifty thousand Watt, they operate under an overall different efficiency according to size and implemented technology. Thus it follows that the more efficient machines should be treated differently from an economic point of view. Although a slight adaptation of prices is defined, still the global industry has not proceeded to according measures of pricing. As identified by the conducted Hellenic company research, essentially all small turbines regardless of size, technology and most importantly estimated efficiency fall into equivalent normalized price range categories meaning, if prices are normalized, a state of the art 50kW turbine will likely have almost the same cost per kW as a 1kW machine.

In previous chapters an estimation on the annual periodic costs of small wind turbines was presented based on the fact that initial annual maintenance costs for large turbines range for 2-5% of the initial investment. Apart from maintenance costs though, this technology (SWT) may present "hidden" or underestimated costs in the form of periodic works which may also vary significantly according to the service providing company. Such costs may include part replacements, transport costs related to the on-site work, equipment (such as mobile cranes) and labor costs, possible insurance costs, the costs of any equipment replacements and the cost of a complete check of the system after 10 years of operation. It is evident that the technology and configuration variability and the fact that the market is yet immature, lead to cost variability which poses a barrier to the accurate estimation of expenditures. Eventually an incorrect initial estimation which underestimates the above may cause an investment to be less profitable or even lead to financial loss.

A factor which directly affects the economic viability of a wind turbine system is the underestimation of wind potential/existing energy source in the urban environment. The accurate characterization of a specific location's annual average wind speed as well as different wind velocities frequency of occurrence pose complicated procedures which are in function with the landscape characteristics. The manner through which landscape can affect wind velocity profiles as well as reduce annual energy yields and thus reduce the economic potential of a location has been examined previously but in order to further demonstrate how the capacity factor is linked with the terrain, Figure 55 is presented. The significantly reduced capacity factors at urban terrains coupled with the lack of measurement standardization as well as measurement deviation in the country may have a potentially devastating effect on the market rendering not viable investments as worthy and the opposite. This in turn may have a negative effect on the credibility of the industry with consumers considering small wind turbines as risky novelties.



Figure 55: Comparison of energy potential in urban and open terrain (Madlener, 2012)

An economic barrier encountered on all RES and especially important to those which are targeting household consumers is the long payback period. Essentially longer payback periods may induce higher risk since market parameters will not remain the same as in the first year of the investment or even constant throughout the projects lifetime (even if prices are guaranteed), potentially setting the investment in jeopardy of not breaking even. In this logic it follows that when competing technologies offer equivalent technical solutions while retaining a shorter pay-back time, they are preferred over others which throughout their lifetime may eventually yield the same or even higher total profit. This may create misconception regarding the goal of a potential investment or even mislead consumers into rendering profitable but slow in returns investments as risky and not worthy.

Particularly for Greece this factor is of importance, especially considering the current status of the RES market. Since the booming of the PV industry, companies in order to promote their products to household consumers or farmers (who in general lacked the economic background to thoroughly evaluate their investment) amidst the unstable macro-economic environment of the crisis stricken country, followed a

marketing strategy focusing on fast returns (mainly attributed to the high FIT and incentives) and shortterm profits in an effort to present such investments as being low-risk or "guaranteed". This strategy succeeded in creating the public misconception that RES investments which do not repay their initial expenses in less or equal to five years are not considered as worthy, resulting in the overlooking of potentially high NPV project for the sake of quicker returns. If the economic evaluation of Chapter 3 is taken into account, where a highly promoting FIT price of $250 \epsilon/kW$ was assumed resulting in a payback period which in almost all average annual wind speeds exceeded a five year period, it is evident how the above phenomenon (which has been identified in literature as well and is especially pronounced for industrial firms (Environmental Defence Fund, 2011)), played its role in preventing potential small wind turbine investors from proceeding to their implementation. The long payback period of small wind turbines is attributed mainly to the high capital costs and also to the rather low, relative to costs, acquired profit since also no other incentives such as tax reliefs for RES producers are granted Important is the fact that the simple payback period does not take into account the time value of money and eventually is a tool that cannot accurately evaluate an investment.

From the above information it can be realized that small wind turbines pose an interesting investment only under specific circumstances which is not applicable or fitting to all consumers. Essentially this creates the economic barrier of a small market size to begin with, thus increasing competition with established RES and not allowing for the manufacturing/importing of an adequate number of machines in order for drop of prices and lowering of capital costs. Other market barriers within the country (either of regulatory/legal or strictly financial nature) introduce further difficulties to the implementation of this machines thus not allowing the market to grow. This in fact creates a vicious circle where the initial market size does not allow for growth and the lack of growth does not allow for the market size to increase. Eventually the above, combined with Market Failure related barriers such as lack of awareness and information, concludes in the potential of the country and market not being realized by investors and other stakeholders alike.

The Hellenic financial crisis and the introduction of austerity measures as part of the memorandum signed between Greece and the European Commission, ECB and IMF forced the country to proceed rapidly to a number of required reforms but also had a negative effect on the market liquidity and capability of investors to retrieve funds in the form of loaning. The high cost of capital coupled with the lack of access to credit to consumers posed a barrier to investors, especially during the most recent crisis years of 2011-2012. Essentially, both consumers and banks were unable to take-on or provide loans, since the first faced massive wage and pension cuts while unemployment rates and taxation kept rising and the second faced grave liquidity problems caused by record losses resulting from the explosion in non-performing loans (NPLs) and their participation in the PSI agreement (Private Sector Involvement in the losses taken in cases of sovereign-debt restructuring (Wikipedia, 2013)) and thus were forced to reject the majority of new loan requests (Euromonitor International, 2013).

Since small wind turbines consist of household-consumer products and do not fall in the category of multi-million investments such as the ones concerning large scale Wind energy, the gradually increasing loan ineligibility of more and more Greeks further devastated the newly (since 2010) emerging market after the issuance of the promoting 3851/2010 law. Furthermore even in cases where loan eligibility would not consist of an issue, under the fear of bankruptcy and future economic uncertainty it follows that the

majority of consumers would not and did not proceed to such slow return investments resulting in the lowering of investment interest and according total loan demands. It is also important to note that since 2010, due to aforementioned problems and change towards the risk perception of financial institutions, banks proceeded in enforcing very strict issuing criteria while demanding additional guarantees which prohibited the granting of consumer loans and essentially created a lack of access to cheap capital (Papadoyiannis, 2013). Evident of the situation is the fact that consumer loan application rejections reached as high as 95% in 2011 while NPLs in the non-card lending segment increased from 15% in 2010 to 19% in 2011 (Euromonitor International, 2013).

A particularly interesting lending sub-category which did not follow the dramatic drop in demand and issuance were the so-called "Green Loans" which aim to finance home energy upgrade projects. Of these projects, "Green Loans" concerned also the implementation of rooftop photovoltaics which are as described the directly competing technological products to SWT bearing a significant number of overall similarities. Unfortunately while such loans for home photovoltaic systems represented an evolving area in 2010, they came to a halt in 2011 following the announcement of the Public Power Corporation that its network was unable to absorb more power from small producers (Euromonitor International, 2013). Currently, although the number of applications continues to increase indicating a growing demand, "Green Loans" concern strictly energy upgrade projects (such as replacing oil with natural gas heating infrastructure and replacement of older window frames to higher efficiency ones) and still do not include SWT or other similar RES technologies.

Regarding government policies aiming to provide access to loans and funds while decreasing associated risks, the program "Energy Efficiency at Household Buildings" has been issued since 2011 providing incentives towards consumers and banks alike in order to increase loan demand and allow the latter to proceed to loan issuances. Although the program has been a success up until now it considers (in the same manner of "Green Loans") only the upgrading of houses heating, insulation and solar heating infrastructure in order to reach higher efficiencies and indirectly save money (Ministry of Environment, Energy & Climate Change, 2010). Unfortunately relevant programs regarding small wind turbines do not exist and as such the lack of government policies to reduce the cost of capital regarding according investments does not allow for the further penetration of this technology.

Following the above analysis the reader may be further perplexed on the reasons Hellenic companies did not consider the general crisis environment to be the most dominant barrier in the implementation of SWT. Although the economic situation of Greece deteriorated until late 2012, it is noted that new requests for connection to the Network in 2012 reached a number of 605 while until July of 2013 increase by another 144. These facts indicate that even amidst this risky and financially grim environment an active interest remained and funds although difficult where available to be retrieved, thus leaving the sole reason for the "freezing" of implementation procedures to be attributed to institutional/legal issues.

4.2.4 Market Failure/ Imperfections

In spite of Greece's high RES potential, the lack of a sound strategic economic plan (apart from the institutional reform oriented National Renewable Energy Action Plan) which would ensure the gradual but steady penetration of RET in the country and establishment of a long-term robust, sustainable and viable

market, has led to the introduction of a number of obstacles which, according to Painuly's framework, belong to the Market Failure/Imperfections general barrier category. These barriers, with poor market infrastructure, lack of awareness and information and high transaction costs being identified as the predominant ones which apply in the Greek market context, have in the highest degree originated from the inadequate and poorly designed plans of the Hellenic government issued from 2009 onwards which resulted in the mismanagement of the Renewable energy sector. The policies followed concluded in the creation of a so-called "Green Energy Bubble" in the country (Ammerman, 2011) with LAGIE facing grave deficit problems and small renewable technologies such as SWT essentially never being fully implemented.

Despite the vast potential of the Renewable Energy sector, which could contribute to the economic recovery of the country by attracting investments, providing capitals (foreign as well as domestic) and creating job opportunities, the mismanagement of the energy sector has led Greece in 2013 to be ranked 37th out of the 40 countries assessed regarding the RECAI (Renewable Energy Country Attractiveness Index) by ERNST & YOUNG, an index which not only takes into account the technical but also includes macroeconomic and energy market parameters (Lyxnaras, 2013). This market mismanagement begun in 2009, with the central policy of promoting RET being prioritized by the government. The MEECC adopted a specific growth model relying on a plan which in retrospect was overly ambitious.

This growth model had in its core the issuance of very high FIT prices in order to fast pace the introduction of RET so to cover the country's EU obligations which at the point lagged behind in penetration to the energy sector. As with other launched Greek government initiatives the medium/long economic consequences were ignored in favor of short term benefits (Ammerman, 2011) and the viability of the issued FIT system was not properly assessed at the time. Due to a lack of control over either the number or location of the applications permitted and the lack of a licensed cap on the energy generation capacity, the result of the followed policy was an unexpected high number of investors responding and obtaining licenses as well as signing contracts with unviable high guaranteed selling prices.

The technology which was heavily promoted was solar Photovoltaics for both household and primarily large scale On-grid applications. Essentially there was a booming increase in the implementation of PV panels, especially on agricultural fields since farmers were granted a number of incentives and assurances regarding approval of their requests in order to switch from producing crops to producing renewable energy. This act, viewed by many as an act of political clientilism (Ammerman, 2011), encouraged (in most cases) poorly informed farmers to undertake loans and sign twenty five year contracts for the installation of PV's which initially had very high returns. This overabundance of request was not met with a rationalized license issuance program which would deny or grant permits according to the local electrical energy generation capacities or absorption capabilities of the Network, thus leading to the gradual result of an overcapacity of installed PV.

This overcapacity is evident if the increase from 53MW of installed power in late 2009 to 1,556GW three years later is considered. Essentially there was an annual capacity increase of 274% in 2010, 215% in 2011 and 149% in 2012. In 2013 PV power increased by 978,9MW thus reaching 2,515GW of nominal power and exceeding the 2014 and 2020 penetration goals by 64% and 14% accordingly. With the passing of the law 3851/2010 the prices per MWh of PV produced electricity were formed as described in Table 24. Also the drop of PV costs per installed kW per year is described in Table 25. As it can be identified by the

Tables, the prices set by law reduced progressively but, as later on realized, not adequately fast enough in order to ensure the viability of the RES funding mechanism (Lyxnaras, 2013). It is evident that although the costs per kW in 2011 were essentially half than the ones in 2009 the guaranteed prices were reduced by only 7%.

Energy Price (€/MWh)					
	Interconnec	cted System	Non Interconnected Islands		
Photovoltaic equipment of up to 10kWpeak for households and small businesses	550				
Photovoltaic equipment in energy producing stations	Power Capacity				
Year	>100 kW	<=100 kW	>100 kW		
February 2009	400	450	450		
August 2009	400	450	450		
February 2010	400	450	450		
August 2010	392,04	$441,\!05$	441,05		
February 2011	372,83	419,43	419,43		
August 2011	351,01	394,89	394,89		

Table 24: 2009-2011 PV	⁷ Generated Electricity Prices	(HEDNO, 2013)
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Table 25: Drop in PV Costs per kW from 2009 to 2013 (Liaggou, 2013)

		Euro per kW (€/kW)					
		=<100	100-500	500-1000	1000-5000	>5000	
prior to 2009		6000	5500	5000	4500	4400	
2009	2nd Quarter	5000	4150	4000	3800	3700	
	4th Quarter	4200	3800	3700	3300	3200	
2010	2nd Quarter	3800	3300	3200	2900	2800	
	4th Quarter	3400	2900	2800	2500	2400	
2011	2nd Quarter	3100	2650	2600	2300	2200	
2011	4th Quarter	2700	2300	2250	2000	1900	
2012	2nd Quarter	2200	1900	1800	1600	1550	
	4th Quarter	1900	1700	1500	1350	1300	
2013	2nd Quarter	1700	1500	1400	1300	1300	

If these prices are compared to the 250 \notin /MWh guaranteed price for SWT, claimed to be the lowest FIT for small wind turbines in Europe (Econews, 2012), the priorities set by the MEECC are evident. Furthermore the guaranteed PV prices were 177-150% higher than the price for electricity production from conventional means (lignite, natural gas and petroleum) if the latter is considered to be equal to 90-100 \notin /MWh at the time. These prices put significant strain to managing the economic parameters of an energy sector which at the point was characterized by a lack of liberalization and was heavily controlled by PPC. In turn PPC in order to fulfill its obligations as both operator of the electrical grid and economic manager of the sector, attempted to pass on the extra RES costs to consumers. This attempt was met negatively by the government and other stakeholders and the final result was PPC being essentially inadequate to cover the FIT prices.

With the partial liberalization of the energy market and the issuing of HEDNO, the management of the RET funding mechanism was no longer an obligation of PPC. Nonetheless within two years of HEDNO's existence the funding mechanism could not further be sustained by the RES levy (Econews, 2001), and reached a deficit equal to approximately 200 million ϵ . It should be noted that the funding mechanism heavily relied on low-voltage consumers (comprised nearly entirely by households and small businesses) rather than industry or other high or medium voltage users. The RES funding allocation percentage as issued by ministerial decision in 2010 was equal to 34,83% for the first, 6,32% for the second and between 0,29% to 19,06% for the last (Hellenic Association of Photovoltaic Companies, 2011). MEECC and RAE responded by consulting 14 individual bodies and adopting a number of measures such as the increase of the RES levy, the re-evaluation of the FIT prices, the re-naming of the RES levy to Special Greenhouse Gas Emission Reduction Tax (ETMEAP) in order to reflect the true nature of the levy as well as include emission charges, urgent taxation on lignite power plants etc. (Econews, 2011).

Unfortunately these measures were proven to be once again inadequate to sustain the deficit of the funding mechanism since after the issuance of LAGIE in 2012 a difference of 142,1 million \in between the expected and real income (originating from the measures) was determined (Energypress, 2012). Due to this lack of income the deficit of LAGIE not only was not decreased but further inflated to reach 331,5 million \in by the end of 2012 with predictions for 2013-2014 being disastrous for the sector. These predictions (Appendix) estimated the deficit to reach 905-2017 million \in by the end of 2014 (B2Green, 2013). Eventually the deficit of LAGIE by July 2013 reached 542,46 million \in with its nihilism being considered a high priority obligation of the country towards the signed Memorandums (Lyxnaras, 2013; Directorate-General for Economic and Financial Affairs, 2013). It must be noted though that due to higher profits from the participation of RES systems in the total energy market of the country and RES levy readjustments (increase by 14,96 \in /MWh (European Commission, 2013)), predictions of the MEECC state that the deficit will be reduced by the second half of 2013 by 153 million \in and continue decreasing in the first and second half of 2014 by 158 million \in accordingly (Sunblog, 2013). Despite this encouraging fact, the goal of zero deficit by the end of 2014 will require further measures if it is to be succeeded.

Amidst this general economic and specific RES market instability climate, caused by the mismanagement of the energy sector expressed by the inability to rationalize the high PV FIT prices, slow down the uncontrolled penetration of PV and increase the RES levy from 2009 to 2011 in order for it to follow in parallel the RES produced electrical energy increasing cost trends and contribute to the reduction

of the RES funding mechanism deficit, it follows without surprise that the attempts of the SWT market to grow and expand according to the provisions of Law 3851/2010 were unsuccessful. Furthermore, exactly due to the above parameters, the unwillingness of the Operator and MEECC to proceed with the license issuance requests and include the small wind turbine produced energy into the overall energy mix thus permitting and promoting the implementation of this technology is evident.

Apart from the above chronologically described events leading to the current state of market stagnation, a significant failure of the small wind turbine sector was the poor information provided, resulting in a partially informed or even misinformed public lacking awareness regarding this technology's potential and constraints. The lack of adequate company marketing policies, independent information regarding small wind turbines apart from those provided by individual supplying companies (at the moment Windipedia.info and HWEA, which also is responsible for large scale wind energy promotion, have solely undertaken this task) and the lack of a professional association specifically for the promotion of this technology via trustworthy according publications have not allowed for interested consumers or the general public to be fully aware of small wind turbine implementation aspects thus not allowing for the built of a trustful and positive attitude towards this technology.

Furthermore the government through MEECC has not conducted adequate efforts for the promotion of SWT and has not proceeded in forms of visual advertising, such as implementation on government buildings/areas. The published reports or informative documents lack details important for the familiarization of society to this technology such as economic details and noise levels while licensing requirements and procedures have partially been included thus creating a sense of uncertainty. Finally CRES, although having conducted substantial scientific work on the promotion of RES in Greece and having published relative studies and guides (such as the Homeowner Guide published under the PERCH Project (CRES, 2011)), did not manage to take small wind turbines out of the shadow of PV. Also CRES did not manage to perform much required (previously mentioned) tests in real conditions which would help in the expansion of knowledge regarding the implementation requirements of this technology in the country. The provided information and guidelines apart from increasing awareness would simultaneously create a sense of public trust towards the installation of small wind turbines and would address other technical and economic related barriers.

Evident of the situation in Greece is the fact that in the National Renewable Energy Policy Plan issued in 2010, it was explicitly stated that in order to ensure the availability of comprehensive information on the processing of authorization/certification and to assist with overall guidance over RET matters, MEECC, RAE, HTSO and the "Invest in Greece" Agency would be responsible for providing adequate information (Ministry of Environment, Energy & Climate Change, 2010). Furthermore law 3851/2010 called for the establishment of a one-stop shop agency for facilitating all issues related to RES development in MEECC which would provide full information to interested parties on all ongoing applications. Three years later, the sole publications specifically regarding small wind turbines in which the technology, costs, constraints, requirements, overall benefits, licensing requirements and procedures have been mentioned explicitly are the ones provided by HWEA which since 2010, either in the form of journal articles and separate published reports (Hellenic Wind Energy Association, 2012; Hellenic Wind Energy Association, 2010) or in the form of conferences and presentations (Georgakopoulos T. , 2011), has publicly promoted SWT. No other publicly accessed documents including such detailed information could be identified during this thesis research and no information was provided by RAE or the MEECC after being requested by the author (although basic information about the technology were included in their websites).

To illustrate how small wind turbines have been treated as a developing technological branch so far by other institutional stakeholders, in RAE's recent opinion report regarding the economic evaluation of different RET, SWT were not mentioned or treated differently than large scale wind energy although they pose a different technology for which different legislative provisions and economic incentives have been issued since 2010 (RAE, 2013). This fact is also identified at the according websites, MEECC's included, where no separate section for SWT is provided despite the obvious differences. Continuing, even though some small wind turbines have been successfully installed On-grid and active interest has been expressed for this technology with more than 958 relevant license requests still pending, RAE chose to include in its analysis solar heating for which the installed power capacity as of 31/7/2013 was equal to zero. This disregard for a technology openly claimed by many as the successor of PV in the Hellenic energy market (PK Consulting Group, 2013), essentially summarizes how SWT have been viewed for the last three years.

The final barrier included in this barrier category deals with high transaction costs originating mainly from time consuming procedures and delays which affect the viability of investments and the finalization of installation works. As explicitly described in previous chapters almost no license request managed to go through the entire licensing procedure or succeed in securing an energy selling contract with the according operator in spite the fact that the operator is obligated by law to proceed in the issuing of such a contract within four months of request (Hellenic Republic, 2010). In essence more than 1000 license requests since 2010 have been delayed indefinitely causing many investors to either withdraw their applications or wait for approval but suffer economic loses from depreciation of purchased equipment or acquisition of less income by keeping capital uninvested.

In turn this fact has had a double effect on the establishment of the market: very small penetration of the particular technology (only six On-Grid installed small wind turbines) and turn of investors to other competing RET[•] namely photovoltaics. Furthermore due to the above, turbine suppliers also experienced losses due to equipment depreciation and reduced sales while investments which could directly or indirectly lead to the creation of employment positions (especially regarding maintenance and installation) were not created. As mentioned previously, essentially these delays and time consuming procedures did not allow for more than 160 million \in to be invested and an entire emerging market to be established in Greece.

4.2.5 Market Distortions

The economic market distortions of the RES energy sector are linked with the SWT Market failure barriers as described in the previous sub-chapter and have played a significant role in both (directly) the inflation of the LAGIE deficit and (indirectly) the unsuccessful introduction of SWT in the country. As described in a recent published letter to the MEECC by the Greek Association of RES Electricity Producers, apart from the data of LAGIE which indicate that the uncontrolled penetration of PV has essentially deteriorated the economic problems of the RES industry in the country in the last two years of economic crisis, the most significant market distortion which has equally affected the inflation of the LAGIE deficit (thus affecting SWT as explained previously) has been the acknowledged incorrect manner of determining the amount of the RES levy or ETMEAP (Greek Association of RES Electricity Producers, 2013). The estimated deficit amount accumulated during the time period between 2009-2012 due to this miscalculation has been calculated to be equal to 350 million \in (Hellenic Wind Energy Association & Greek Association of RES Electricity Producers, 2013). Essentially this market distortion has also affected the social barriers towards RES in general since the current manner of calculation and characterization of ETMEAP has created the misconception that they consist of uneconomical means of producing energy which charge consumers with extra taxation for their funding (Tsipouridis, 2013).

Before continuing with the analysis of this barrier the *System Marginal Price (SMP)* concept will be explained. The SMP is the price which all producers and suppliers who inject energy into the System (including RES producers) receive from the daily energy market planning and is calculated by taking into consideration the combination of the offered prices and quantities which are subjected daily by the available power plants and the hourly load demand for electricity, formed on a daily basis by consumers. Production units are classified according to their bids in ascending order, starting from the lowest price offered for a fixed amount of energy quantity covers fully the desired load and in essence, the system marginal price coincides with the offer of the last unit required to be operated to meet the demand. In order to ensure the protection of consumers and conditions of healthy competition as well as the ability of producers to cover their fuel expenditures, an upper and lower limit regarding the offered price has been administratively issued which is equal to $150 \notin/MWh$ in the first case and equal to the variable cost of the energy unit in the second case (RAE, 2013).

Until April of 2013 suppliers of electricity, such as PPC, bought the RES produced energy injected into the System at the SMP from LAGIE while RES producers received payment from LAGIE which was equal to signed FIT prices. Nonetheless Greece had issued FIT prices for RES since 2006 and more specifically for the technology of small wind turbines since 2010 which are, as described earlier, essentially higher from the daily calculated System Marginal Price. Practically this means that a difference between the SMP and FIT price was created thus also creating a difference in the economic balance of LAGIE. This difference was required to be covered by the RES funding mechanism of LAGIE which in turn continues until today to be mainly funded by the RES levy or ETMEAP described in the previous sub-chapter Furthermore, the more RES produced energy is injected into the system the more the SMP is reduced since (for reasons related to energy sector's economic technicalities which go beyond the scope of this thesis) the RES energy is not taken into consideration for its calculation. Evident of the situation is the fact that in March 2013 were the penetration of PV had reached a critical point, the SMP was equal to $10 \notin MWh$ while the average price of 2012 was equal to $62 \notin MWh$ (Energypress, 2013). It follows that the lower the SMP was the greater the difference needed to be covered by LAGIE's funding mechanism which was and still is dependent to ETMEAP. Since ETMEAP was impossible to continue increasing amidst the economic crisis due to the fact that it strongly relies on end-consumers, as described in the previous chapter, the deficit continued to grow.

According to HWEA and the Greek Association of RES Energy Producers the SMP at which Suppliers of electricity bought electrical energy was inherently incorrect and since it compared the FIT prices RES received not with the total cost of producing energy via conventional means but by only a fraction of that, represented by the SMP (HWEA, 2012). Essentially in its core this methodology was unable to include and quantify the external costs of conventional energy production thus not reflecting the true social and economic benefit of RES usage. Furthermore, after specific studies conducted already circa 2011 (Association of Photovoltaic Energy Producers, 2012) by esteemed foundations and institutions, such as the Foundation for Economic & Industrial Research and the National Technical University of Athens, it was revealed that due to the distorted calculation methods and overall approach, the ETMEAP instead of being exclusively used in favor of RES producing methods, it indirectly also benefited energy Suppliers to a percentage of almost 60% while simultaneously increased LAGIE's funding mechanism deficit (Association of Photovoltaic Energy Producers, 2012; HWEA, 2012; Hellenic Wind Energy Association & Greek Association of RES Electricity Producers, 2013). If this indirect funding is quantified regarding the last four years the amount "deducted" by the costs of energy purchasing of Suppliers, such as PPC, has been at least equal to 400 million \in (Greek Association of RES Electricity Producers, 2013).

Apart from the above this indirect non-physical funding has allowed for the creation of the misconception to consumers that the cost of fossil fuel based energy production methods is significantly smaller than the one of RES (since they are being forced to pay for an ever increasing ETMEAP levy) and also has facilitated the cash flow transactions towards conventional energy producers which essentially are being paid by the Suppliers (PPC) through the according Operators, whereas on the other hand RES producers payments have been delayed on a six month basis regularly (Hellenic Wind Energy Association & Greek Association of RES Electricity Producers, 2013).

In April 2013 the Hellenic Government decided to take into consideration the published findings of the aforementioned institutions as well as the calls from the RES energy sector stakeholders since the deficit of LAGIE was derailing and the goal of its nihilism, set by the Troika, was beginning to fade. By passing the Law 4152/2013, the Government partially corrected the manner in which the RES Funding Mechanism's received income from conventional electricity Producers and Suppliers by now considering that "the amount paid must reflect at least not the SMP but the Weighted Average Variable Cost of conventional thermal power plants and must be proportional to the energy injected, by priority of usefulness, on the transmission System and Distribution Network of the mainland and associated islands as defined in Article 9 of Law 3468/2006 with the methodology specified in the Power Exchange Code" (Hellenic Republic, 2013). By this law the average price per MWh (initially being equal to the SMP) paid by Suppliers increased by 84% reaching 59 €/MWh (HWEA, 2013).

Unfortunately this measure came into force late and did not introduce a radical reform in order to resolve definitively the deficit issue of LAGIE. Furthermore it still does not reflect the actual cost reduction achieved by the penetration of RES in the energy market of the country. The Hellenic Association of Wind Energy already by August 2013 had requested the further increase of the price per MWh paid by Suppliers to be issued according to the Weighted Average Variable Cost of the most expensive of conventional energy production units (introduced or replaced by RES stations), increased by a capacity credit percentage (15%-20%) representing the guaranteed power supplied by RES in the System (HWEA, 2013). The according price calculated to be equal to $85 \in /MWh$ would suffice for the rationalization of the aforementioned distortions. Such an increase has yet to be issued by the MEECC.

The evident effects of the particular market distortion over the establishment of the SWT technology in the country have been explained in the previous sub chapter. Essentially the ETMEAP cost shift to RES and indirect funding of Suppliers which resulted in the growing of LAGIE's Funding Mechanism deficit inhibited the introduction of (other than PV) RET or their establishment. The ambitious plans of the government and the high FIT price for small wind turbines that would potentially further increase the economic issues faced by the MEECC were indirectly put on hold, by the ministry not pressing for the finalizations of the licensing procedures by the according Operator, for the sake of rationalizing the growing deficit. Although this approach was catastrophic for the maturity of a small wind turbine market sector in Greece, it can be partially justified if the grave economic status of the country for the least five years is taken into account. Nonetheless if SWT are eventually to be implemented significant changes are imperative.

4.2.6 Social, Cultural and Behavioural

Social, Cultural and behavioral obstacles are of particular importance to the introduction and establishment of every new RES technology. Especially for the case of wind turbines they have been proven to be significant since local opposition has stopped the progress of multimillion projects in the past. Despite that fact, analogous in depth analysis regarding the causes of opposition to the use of SWT have not been performed and considering the perspective difference between large and small scale, the conclusion that further detailed studies are required can be drawn. Also the fact that Hellenic companies do not regard social barriers as a priority may indicate the above conclusion as well. Painuly recognizes two main barriers which obstruct the penetration of RES and are applicable to the case of small wind turbines based on a distinction of willingness to implement and population size: lack of consumer acceptance and lack of social acceptance. The first barrier considers consumers or the part of population which are willing to implement RES energy production methods but still do not accept a particular technology due to related problems while the second barrier regards the general stance of society against the penetration of a new technology by including also the population parts which are not willing to implement RES or allow others to. Both barriers are interlinked and mutually connected and while can be separately analyzed must be treated simultaneously if they are to be overcome.

The first social barrier created by the lack of consumer acceptance has been indirectly addressed by the previous barriers analysis. As described, inadequate information provided by governmental and nongovernmental stakeholders regarding this technology, its associated benefits and constraints and most importantly the economic perspectives of an according investment has kept SWT in the state of an "unknown" product. This fact has had potentially a double effect on the growing of the specific market: essentially it has driven consumers towards other well-known or well-advertised technologies, namely Photovoltaics, and has created the misconception or misassociation of SWT being risky, underperforming and expensive commodities. Furthermore as it has been stated before the lack of clear, simplified and fast licensing procedures as well as the lack of implementation of regulations and frequent legislation changes coupled with the highly unstable financial state of the country in the last five years have not provided a stable regulatory/legal and economic environment for investors, thus further hindering the acceptance of the new technology. Finally safety issues are considered a major obstacle to the acceptance of SWT in Greece since the lack of standardized procedures which can guarantee the safe operation, installation and maintenance of these machines increase the risk of hazardous accidents (Syngelakis, 2006). As stated by leading experts of CRES no guarantees are provided regarding the structural integrity of SWT apart from the ones given by manufacturers and as such the public is unwilling to overtake the associated responsibility.

Apart from the above, other parameters such as aesthetic considerations and hazards associated with the technology have kept consumer interest low (Syngelakis, 2006). The fact that numerous designs of different quality and characteristics exist, although may provide a variety of technical options, do not facilitate the uniform aesthetic acceptance of SWT machines (Gipe, 2004). Especially in the case of roof installed turbines the lack of a dominant design, which could present an iconic form or an archetype to be established in consumer minds (such as the one established for large scale wind energy: namely the threeblade-tubular-tower machine), creates more confusion and difficulty in accepting the visual intrusion. The variety of axis of rotation orientation, different tower, number of blades, tail vane, other infrastructure and overall shape size are variables which may be difficult to be accepted especially by consumers in countries which resistance to change is high or new technology adoption is slow. Thus the implementation of stationary, not moving and of low visual blockage competing established technological products (PV) may be preferred.

Although consumer acceptance is considered an important factor, when social barriers are considered, the focus shifts more towards the barriers imposed by the social acceptance of a new technology by all key stakeholders but also mainly by the part of the population which will not become perspective investors and will not choose to proceed to the implementation of a RES system in the first place. Such groups, not only will they not contribute to the expansion of a new RES market but also will introduce obstacles for potential consumers and investors regarding the installation of machines in their vicinity. By either disregarding the technology of no use, by preferring traditional energy production methods without considering the consequences of this choice or by simply resisting to change for a number of reasons they will oppose in the finalization of a project even if all legal procedures and terms are fulfilled.

In Greece although wind energy is considered to enjoy public support (Kaldellis, 2003) and a significant number of large wind farms exist (indicating the above) relevant studies have shown that such local obstacles are a fact. Nonetheless according adequate studies specific for small wind turbines do not exist. Although this technology differs substantially than its large scale counterpart, especially regarding the deployment proximity to residences, if the findings of international literature are taken into account, most likely SWT opposition in the country is to be faced by development opponents who although recognize the potential benefit of the technology, do not agree with its siting within their locality (Taylor, Eastwick, Lawrence, & Wilson, 2013). The latter concept is described by the acronym NIMBY which stands for N(ot) I(n) M(y) B(ack) Y(ard).

The term dates from 1980 and its origin is attributed to Nicholas Ridley, a British Conservative MP, while others trace it to Walter Rodgers of the American Nuclear Society. Although occasionally, loosely and uncritically used to describe any local opposition regardless of underlying motives, NIMBY considers opposition to projects to originate from three distinct perspectives: the ignorant and irrational response to a new project, the selfish response based on limited self-interest and the negative response motivated by concerns about local impacts (Burningham, 2012).

The first perspective has been criticized by sociologists who argue that active opponents cannot be treated as always having incorrect or too little information which needs to be simply corrected since it undermines the capability of individuals to judge and weigh the relevance and usefulness of information. Also empirical studies have revealed that often opponents are even more knowledgeable than the implementers and that if the first are treated as ignorant opposition will be exacerbated. Nonetheless it should be pointed out that the lack of information is a significant and existent problem for the case of Greece and if not addressed will have devastating effects to the penetration of this particular technology, especially since siting is on an urban level and includes safety concerns.

The second perspective is regarded by various researchers to fall within the boundaries of the free market system where an individual's acts of self-interest are considered to be rational and cannot be condemned. As such the opposition triggered by the lack of self-interest is justifiable. Other researchers disregard the idea by arguing that rational choices overcome self-interest. In any case although according opposition can be addressed by delivering benefits to local communities (as relevant studies considering large scale wind energy have shown), regarding small wind turbines this is a problematic option since this technology concerns household consumers who decide to proceed to a private investment in order to foremost gain personal benefit. If the economic data provided by this thesis are taken into account, investment characteristics and legal uncertainties may prove the task of including the nearby community in profit sharing to be impossible and most likely unwanted. As shown previously even in the case of a 50kW turbine implemented in a Greek island, where payback time was optimally estimated to be over 7 years and financial yields could be substantial, a further reduction of profit by distribution of a percentage to neighbors would immediately render the investment as unattractive. Apart from this fact such strategies could be considered as bribery and could further exacerbate opposition. The only possibility would be a community owned wind turbine where the investment and profits are shared but this goes beyond the concept of SWT as being household consumer products.

The third perspective of NIMBYsm may be the most fitting towards the opposition expressed over the implementation of small wind turbines. Negative local impact concerns include noise, safety, health risk, visual, aesthetic and environmental related issues which originate mainly from unresolved technical barriers (Gipe, 2004; Syngelakis, 2006). Since these factors would highly apply to the Greek context, they are further analyzed in the following paragraphs.

As discussed in the technical barrier subchapter, noise is considered to be a predominant issue to the widespread implementation of SWT. Although the social opposition to the installation of turbines due to noise complaints and claimed health related problems is well known to manufacturers and suppliers alike, little work regarding the quantification and assessment of the problem in the context of an urban environment exists. Although this social barrier which leads to the lack of acceptance of this technology has been studied extensively with regard to large scale turbines, the drawn conclusions have not been confirmed to apply in the small scale (Taylor, Eastwick, Lawrence, & Wilson, 2013). The different scale essentially means different noise characteristics while the different siting proximity to households changes the intensity of noise problems. Also as hypothesized in a study conducted by Swedish researchers Waye and Ohstrom, different large wind turbine types and accordingly different mechanical parts which comprise them may be the cause of different levels of noise perception and annoyance (WAYE & OHRSTROM, 2002). In the particular study five different three-bladed HAWT were considered while the noise levels in all cases were measured to be equal to 40dbA. If the variety of small wind turbine design types (as described by chapter 2) is taken into account, a logic assumption can be established, concerning the findings of the above report,

on the fact that they may be applicable to small wind turbines as well. Furthermore by considering relevant large scale turbine studies there are reported health effects which are statistically correlated with wind turbine noise pressure levels over 40dbA and are also in function with sensitivity to noise, visual constraints and overall stance to wind energy. These health effects, described by Dr. Nina Pierpont as "Wind Turbine Syndrome" (Pierpont, 2009), are debated on whether they originate from the annoyance experienced due to the nature of noise or more directly from the emitted infrasound and low frequency turbine noise (ILFN). Nonetheless they are further linked to a range of health disturbances ranging from sleep disturbance, headaches, dizziness, and heart problems to psychological well-being (Baxter, Morzaria, & Hirsch, 2013). These effects have not been yet explicitly studied for small wind turbines.

Despite the lack of the according studies, an interesting research conducted by Jennifer Taylor et all of University of Nottingham has investigated the relation between noise levels and noise perception for small wind turbines in the UK. Essentially the results of the survey indicated that when a small wind turbine is within the visual range of nearby residents, reports for noise levels are more frequent and of higher level. Nevertheless the proximity of small wind turbines did not have a negative effect over the attitude of participants towards this technology. Furthermore the study did not identify any connection between age or sex to the perception of noise and symptoms but found a strong influence of personality characteristics to the overall results.

More analytically people with higher Positive Affectivity or lower Negative Affectivity perceived less noise while those with higher Frustration Discomfort and Intolerance to Emotional Frustration reported increased turbine noise (Taylor, Eastwick, Lawrence, & Wilson, 2013). Also a strong correlation between individuals who exhibited higher Negative Oriented Personality (NOP) traits such as Negative Affectivity, Neuroticism and Frustration Intolerance with reporting of health symptoms was identified (Taylor, Eastwick, Wilson, & Lawrence, 2012). The findings of the particular research, which linked visual contact and negative attitude towards wind power with increased sound perception, concluded to the important fact that the first parameter did not affect any health symptom reporting while the second had a significant impact on the matter. Practically this translates into: negative attitude over wind turbines coupled with individual negative oriented personality traits increases noise perception which in turn increases health symptom reporting. This is a finding which implies that the existence of "Wind Turbine Syndrome" for small wind turbines, contrary to previous researchers, is attributed (partially) to individual personality traits rather than actual emitted sound characteristics thus discarding its physical or medical connection to small wind turbines. According SWT specific researches have not been performed for Greece since the penetration of this technology is still small. Nonetheless, it follows from the above research that conducting such surveys in order to early identify connections between Hellenic population general personality traits and exaggerated anticipated noise with ill health reporting is crucial if according social opposition is to be addressed effectively or even be prevented.

The Visual considerations pose an equivalently important issue regarding local social acceptance which is in function with personal preferences and characteristics as well as the type of landscape in which the turbines are to be installed. Although visual impacts are not as grave as in the case of large turbines since both construction works, tower heights and rotor diameters are of a significantly smaller scale, especially regarding Greece landscape obstruction on a local level is a factor which undoubtedly has and will create opposition in the future.

If the analysis concerning the Hellenic wind potential presented in Chapter 3 is taken into account, the island areas of the country pose an ideal opportunity for SWT implementation. Nonetheless the economy of most islands is based on tourism due to their high archaeological, historic, ecological and environmental value and as such any potential blockage of scenic views by tall structures is almost certainly to be met with complaints from the local community. Also exactly due to such locations high scenic value, the effect of visual impact over overall social acceptance is intensified (Heagle, Naterer, & Pope, 2011). Concerning installations in the mainland and in particular in highly populated areas or main urban centers, the absence of a deployment plan and according legislation (which could clarify the density of turbine installations, allowed distances etc.) and the potential unorderly siting which could lead to perceived visual pollution would lead to strong local opposition. Although the issue is comparable with cell phone towers, water towers, and utility poles siting, the movement of the machines which may bring an unwanted dynamic appearance to the area (Wineur, 2007) and the impossibility of disguising them essentially further exacerbate the problem. Furthermore the uncommon design characteristics of SWT may prove to be difficult to be visually integrated with the cultural elements of traditional architectural designs, such as the ones existing in the island complexes or in specific mountain areas, thus further increasing opposition. Also the high probability of locals not being accustomed to viewing energy generation stations in general, regardless of the above location factors, combined with the novelty of designs will most likely exacerbate visual impact and negative reactions (Heagle, Naterer, & Pope, 2011). Since these aspects are highly subjective, without according case studies it is currently impossible to describe the extent of such social opposition in Greece. Nonetheless as with the case of noise annoyance, these studies would be imperative if according social opposition is to be reduced.

Another cause for opposition is the threatening to local or migrating wildlife such as bats and birds especially by turbines of the upper output power range which can be mounted to over 30 meter high towers and have sufficiently large swept area diameters. Although Hellenic legislation has included the issuance of environmental permits in case of implementing small turbines in locations close to Natura 2000 areas and coastal zones located at a distance smaller than 100 meters from the water line to avoid negative interaction with wildlife habitat, perceived potential associated risks are a source of local opposition in which also NGO may participate. Since the matter is of significance, considering the outmost goal of implementing RES is the protection of the natural environment, such matters must not be taken lightly or considered trivial. Nonetheless relevant studies are essential to determine whether an actual problem exists or complaints and opposition originate from NIMBYsm or lack of knowledge.

Different to large scale wind turbines which rotate at much lower rotational speeds, are sited at distances which may even reach 300 meters and no longer implement truss towers where birds may likely attempt to land and rest, small turbines reach high rotational speeds, have more frequent direction (yaw) changes, can be closely sited (Appendix) and installed near tree tops. Nonetheless SWT do not reach the height of their large scale counterparts nor do they cover such a wide swept area, thus restricting the problem since most raptors or birds of prey (potentially endangered species) fly at higher altitudes. Also in populated urban centers avian wildlife is seldomly consistent of such species. The impact of installed small wind turbines is highly location related and as such studies equivalent to those performed for large scale wind farms in Greece relative to this barrier are required.



Figure 56: Birds resting on small turbine and proximity of wind turbine to mediteranean tree top line (Allianz, 2010; Niagara Wind and Solar, 2013)

From the above it is evident that such problems, originating from NIMBY's third perspective, are highly complex and include a number of variables which require approaches which go beyond the nature of simply adopting technical or economic measures. Also in many cases social opposition to new technologies cannot be simply attributed to NIMBYsm since the benefits of the technology may not be recognized in the first place or opposition could be based on an overall negative perception of wind energy on a global level. As a matter of fact many researchers (although slightly different definitions of the phenomenon are used) disregard NIMBY whatsoever or state that it is inadequate to explain or justify local opposition. In any case (as it has been claimed throughout this sub-chapter) the only way to quantify and assess potential social implications because of SWT, if related barriers are to be essentially prevented and reduced in order for On or Off grid applications to increase in Greece, is through extensive testing under real conditions.

5 Proposed Measures-Solutions

In this chapter proposed measures to the barriers faced by the technology of small wind turbines will be assessed and presented. The analysis will take into consideration the previously described country specific obstacles and attempt to provide applicable and viable solutions which will target the most significant barriers identified. International literature and according studies/roadmaps issued for other countries and especially for those within EU (since they are obligated to comply to the same regulations regarding the management of their energy sectors according to the relevant EU Directives as Greece) will be used as references and their according conclusions and propositions will be suitably applied for Greece. Furthermore the considerations of Hellenic small wind turbine supplying companies will be incorporated thus permitting the stronger link of this analysis to the Hellenic renewable energy market sector. The analysis will begin with the critical assessment and realization of the most significant barrier to the establishment of the small wind turbine technology in Greece, as determined by the author according to Chapter 4 information, and after relevant measures are described it will continue with regard to other propositions in order of their significance.

5.1 International Approaches

To compensate for market failures, non-internalization of external costs and relative barriers to the deployment and growth of RES in order to achieve competitive open markets in the future, Europe has a range of policy measures in place including support schemes, standards, and administrative rules to promote renewable energy development (European Commission, 2013). These measures can either work at a micro level addressing the barriers directly in order to remove them or work at macro level addressing the barriers indirectly, aiming to create market conditions were such issues can be ignored or bypassed. For example, setting up information centers, establishing codes and standards etc. address the barriers directly, whereas increasing energy prices through pollution taxation addresses the barriers indirectly (Painuly, 2001).

One of the micro level EU approaches to the issues faced by SWT over their deployment was the launch of the Intelligent Energy Europe's (IEE) Wind Energy Integration in the Urban Environment (WINEUR) program aiming at assessing the viability of this technology for European Markets, understanding relative barriers and propose relevant solutions. This program was completed on 2007, focusing mainly over Northern and Central European countries such as the UK, Netherlands and France. Although this project identified barriers during a pre-financial crisis stricken European where both the particular RES energy markets and overall economies of the EU countries involved presented substantial differences than that of Greece, certain general conclusions are applicable to the obstacles faced by this technology in the country. More specifically Wineur resulted on the following actions included in Table 26, where \Box indicates the party responsible for the initiative and X indicates direct involvement. Through the program it was identified that governments are predominantly responsible for initiating procedures and adopting measures which will directly involve and affect all other relative parties. In that sense the conclusions of this research project indicate that government related issues are of the highest importance,

which is in agreement to the overall analysis conducted by this thesis. Already this approach highlights the path in which Greece must follow to overcome its country specific obstacles and thus Wineur's conclusions can be applicable for the Hellenic market as well.

Action	Government	Suppliers	R&D Institutions	Consultants	Certified Bodies	Building Owners	Building Sector
Investigate and compare the efficiency of different UWT types		х	х	х		х	
Perform LCA (Life Cycle Assessment) of UWTs and the long term price development per type and model		х	х	х			
Carry out a study to estimate the overall energy potential of UWTs		х	x	х			
Develop a R&D programme for UWTs		Х	x	х	х	х	
Introduce financial incentives similar to those for PV		х	x	х		х	
Develop safety norms for VAWT	х	х	x	х			
Develop noise norms UWTs	х	х	х	х			х
Develop a set of guidelines for the construction integration of UWTs	х	х	x		х	x	х
Develop a certifying protocol for UWTs			x		х		
Certify UWTs			х		х		
Include UWTs in the building regulations (building permit, local plan, etc)		х		х			х
Harmonise laws and regulations on national, European and international level							
Grant exemptions from the administrative costs							
Exempt UWTs from the building permit regulations in industrial zones				х		х	х
Develop a simplified method for identifying optimal installation sites		х		х		х	х
Initiate demonstration and pilot projects	х	x	x			x	x
Develop an objective information package	х	x	x				

Table 26: Recomendations of Wineur Project for the growth of the SWT market in Europe (Wineur, 2007)

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Table 25 nonetheless includes a number of specific actions which, at the time being, are inapplicable for the case of Greece. Specifically, considering that the countries taken into account have relative manufacturing industry and possess the necessary infrastructure for experiments as well as Institutions which directly are involved in relative research for small wind turbines (for example in the Netherlands at the time the report was written eight developers and manufacturers existed while TU Delft conducted a significant and broad research program with a special focus on wind in urban areas including wind flow around buildings, performance of SWTs placed on buildings and the associated optimization (Wineur, 2007)), the above recommendations heavily rely upon R&D to further the use of this technology and tackle relative obstacles, such as the overall energy potential estimation of machines or development of noise norms. In Greece, as identified by Chapter 3, such an industry does not exist and hence R&D is practically non-existent or is severely limited to non-industry parties, such as universities and CRES, which have not prioritized this technology in their research, as identified by the lack of a substantial number of relative publications.

A particular limitation of the Wineur project was the inability to further categorize the research's proposed recommendations by timelines, thus essentially not specifying their priority. Not being able to select or identify which measures need to be adopted first in order to facilitate further actions, does not contribute to the correct planning and solely provides with sound but undistinguishable between short-term and long-term actions. This limitation was not encountered in the US National Renewable Energy Laboratory's (NREL) Built-Environment Wind Turbine Roadmap report which identifies key barriers to the development and deployment of small wind turbines (particularly for the built environment) and outlines a strategic approach to addressing these barriers. The roadmap, issued in 2012, outlines stakeholder actions to overcome identified barriers categorized as near-term (0-3 years), medium-term (4-7 years) and both near- and medium-term, with long-term actions being impossible to project for such a rapidly evolving industry (National Renewable Energy Laboratory, 2012).

According to NREL's Roadmap results which have been issued based on the specific barriers identified in the US market, the near-term actions require immediate attention which will either address barriers without delays or be a precursor to following medium-term actions, whereas the medium-term actions focus on the development of testing and design standards for the gradual establishment of a competitive and growing SWT industry. Actions classified as both near and medium term require the immediate as well medium-term effort to reduce SWT barriers and improve the industry (National Renewable Energy Laboratory, 2012).

Table 27: Required time-classified Stakeholder actions for the promotion of Small Wind Turbines in the US (National Renewable Energy Laboratory, 2012)

Stakeholder Actions				
Near-Term	Medium-Term	Near and Medium Term		
Production of Consumer Guide and Fact Sheets	Creation of best-practice recommendations	Creation of a reliability database		
Production of Risk and Hazard Focused Fact Sheets	Adaptation of data assessment tools	Conduction of BWT test measurement campaign for loads and yaw rates		
Creation of standardized resource data assessment protocols	Instrumentation of existing BWTs	Producion of case studies		
Survey and analyze existing data	Conduction of model validation at demonstration sites	Conduction of site wind resource assessment through measurement and validate analytical model(s)		
Investigate and compare wind resource modeling methods Providing recommendations to governing bodies and standards		Building of demonstration sites		
	Conduction of turbine research and development	Conduction of turbine testing		

As identified by the above Table, safety is a primary concern and although no near-term actions exist that quantifiably address safety due to the lack of measurements and model results, an early effort is conducted to address it via indirect means' namely Fact sheets and introduction of safety regulations in standardized resource assessment protocols. Essentially the first stage of stakeholder actions is establishing a network of information which will assess and present to the public credible information regarding this technology's technical, economical and other aspects and further analyze technical issues which still have not been thoroughly looked into (such as detailed urban wind resource assessment, turbulence and directional variability in the built environment, three-dimensional wind speed profile and distribution etc.) in order to ensure that this technology is associated with a safe and eco- friendly way of producing energy at a local level. In the second stage of stakeholder actions acquired knowledge is to be utilized in order to proceed to concrete actions which will directly address identified barriers. R&D will play a significant role, where detailed assessment tools will help with the accurate prediction of economic benefits per installation site and actual construction of models and testing at demonstration sites will allow for the validation of previously created models and eventually technical growth, full and complete standardization and reduction of overall costs. For actions both of near and medium term, tackling technical issues and creating databases which will include failure patterns, design requirements and detailed wind measurements as well as increasing public awareness through the use of real testing are essential.

The propositions of NREL in comparison to the recommendations of the Wineur project do focus more on overcoming technical issues and follow primarily a micro-level approach in which the direct resolving of risks related to technological uncertainties will eventually lead to overcoming institutional, economic and social related issues. Although this approach may be sound and effective for the US, it would not be directly the most fitting for Greece since, as it has been already argued, even if technical barriers are addressed the inability of the governmental and non-governmental stakeholders to follow the existing legislative framework and the RES energy sector failure/distortions will not allow for the growth of this sector. Practically this translates into the fact that even if the technology of SWT was in 2013 fully mature, the current inability of the Hellenic energy market to allow for the introduction of innovative solutions in an already problematic sector which is facing deficit problems and is poorly managed, without any radical regulatory changes would doom such an endeavor. Nonetheless certain recommendations can be used for the case of the Hellenic market as well.

Greece at the moment does not possess an action plan specifically for the promotion of small wind turbines which can successfully target this technology's barriers in the Hellenic RES energy framework. Also since Greece does not possess at the moment manufacturing industry or substantial R&D facilities, addressing the technological inefficiencies of small wind turbine technology directly as described in the NREL roadmap is currently not feasible. As such economic and legislative policy approaches aiming to remove or bypass existing barriers must be implemented. For this reason a number of the above recommendation approaches from both the researches of Wineur and NREL will be utilized and combined in the following subchapters in order to identify possible solutions and result in a final conclusive Table where proposed measures will be both categorized by timelines and stakeholders.

5.2 Tackling the Predominant Barrier

5.2.1 Identification

Greece, since 2008, is struggling to recover from arguably the worst economic crisis of its last 100 years of history. In order to receive economic aid in the form of loans so to avoid bankruptcy, exiting the Eurozone and returning to its previous currency (with the consequences such acts would have to the future of the country and the European Union itself) and to cover a no longer viable financial debt, the country agreed in May 2010 to conform to a number of economic measures imposed by the International Monetary Fund (IMF) and European Union (International Energy Agency, 2011), described in two signed memorandums. Despite the fact that the austerity approach has resulted in heavy cut backs in the public sector investments and have heavily affected the entrepreneurial activities in the country, included in the clauses of the memorandums are indirect measures for the promotion of renewable and sustainable energy technologies in order for the country to reach its RES policy targets, which are in accordance to the Kyoto Protocol and EU Directives, by taking advantage of its natural resources. In essence the signed memorandums have ensured that the country will keep a steady course towards achieving its RES obligations.

As identified by Chapter 4, the willingness of the Hellenic Government to boost the penetration of RET in the country by the issuance of an ambitious plan expressed by law 3851/2010, was partially unsuccessful and created a deficit in the main RES funding mechanism which had catastrophic consequences over On-grid SWT deployment. The sound priority set by the Troika for the economic recovery plan of LAGIE's deficit essentially shifted the focus of the according stakeholders and resulted in

putting aside the implementation of this technology since the Government, via the according ministry of MEECC, did not further apply pressure for the finalization of the licensing procedure of over 958 requests and did not allow for the establishment of this market. Although the later reviews by the Troika committee members and the Commission's RES progress report pointed out the immediate need for the restraining of further unplanned and uncontrolled penetration of Photovoltaics and the increase in penetration of other RET, according actions were not taken resulting in the complete market stagnation of the originally promising small wind turbine technology.

Taking into account the interviews conducted for this thesis, the majority of small wind turbine suppliers contacted, identified Institutional/Legal as well as Market Failure based issues when asked to name factors that inhibited the implementation of this RET (Figure 60). Although their prioritization was different according to the focus of each company (On-grid/Off-grid applications), nearly 90% of companies mentioned relative obstacles. From the conducted research it was further determined that, particularly Suppliers of larger scale (50 kW) On-grid turbines, publicly expressed their dissatisfaction over the lagging of legal procedures, leading to investment withdrawals and monetary losses, while argued that law 3851/2010 despite its flaws was accurate enough for the introduction of this market (Miniwind ltd, 2012; M $\alpha\theta_i \delta \sigma_i$, 2012). Furthermore, although the Off-grid small wind turbine sector is essentially largely unaffected by the current legislation since it is decoupled to the energy market, the missing or unclear laws and regulations specifically regarding the deployment of SWT which could fundamentally address technical and social barriers further also underline the significance of such related obstacles.

By the above facts as well as the overall analysis conducted in Chapter 4 the conclusion that the predominant barrier faced by SWT during the time period of 2010-present, which has not allowed for the market of especially On-grid small wind turbines, has been the inability of Government stakeholders to follow or impose the existing regulations and laws due to their existing fundamental flaws (identified mainly in the existence of complicated and costly licensing procedures), missing market infrastructure and regulations (deployment plan) and restrictions of the renewable energy sector imposed from an economically unstable environment (LAGIE deficit) and system distortions (miscalculation of ETMEAP).

5.2.2 Stakeholder Actions

In order to "jump-start" this stagnant market regarding On-Grid applications and also further promote the Off-grid applications, the establishment and immediate implementation of measures is required which can by-pass the current market and legislative issues, thus working initially at a macro level approach. It is important to note that attempts to confront the current issues of the RES energy sector directly and establish simultaneously the technology of small wind turbines will be unsuccessful since the problem is highly complicated involving a number of non-SWT related stakeholders and requires time consuming reforms. Since the FIT system issued by law since 2010 has never been implemented and is interrelated to the licensing procedure in which non-governmental stakeholders have kept on hold nearly all applications since 2010, the implementation of a new legislative measure is required which will reduce bureaucracy, the amount of involved bodies and thus associated risks translated into potential economic loses while accelerating procedures. A legislative measure that could essentially allow for the immediate installation of turbines in On-grid applications without further increasing the deficit of LAGIE's RES funding mechanism and potentially without the need for the lengthy licensing procedures would be the allowance and introduction of Net Metering. The Net Metering system is the simplest way to connect a household production unit and does not require special metering or prior arrangement and notification (CRES, 2011). This policy allows for utility consumers to operate their own RES facilities and consume their produced energy while being simultaneously connected to the grid. When produced energy surpasses the energy consumption of the household then surplus energy is directed to the grid. Essentially with this policy the RES produced energy is compared to the supplied energy provided by the utility energy company (in the case of Greece PPC) during a specific time period and the net outcome, obtained through the use of a two direction electricity meter, is used for the calculation of the final household energy bill. The deduction of energy outflows from energy inflows can decrease significantly electricity bills or even potentially eliminate electricity costs. According to the issued legislation Net Metering may provide directly an income to the user if the surplus directed to the grid is being compensated by the utility company or sold at a retail price (although in such cases an extra cost of Network usage may be applied by the Network Operator) (Econews, 2013).

Net metering originates from the US where various forms of this policy already have been implemented since the 1980's, whereas since 2005 all U.S. utilities are required to offer net metering "upon request" to customers. In order to promote the use of RET without the aid of FIT systems, the use of net metering without any added interconnection fee has resulted in 10 billion \$ in private investments and 2,5 billion \$ in savings for schools and public agencies in the state of California alone (Beach & McGuire, 2013). Despite the popularity of this system in the US, in Europe the introduction of net metering has been slow due to the low price of conventionally produced electricity as opposed to the high electricity production costs from RES which did not allow for interesting consumer investments. Only in certain EU countries, such as Belgium, Denmark, Cyprus, Italy and the Netherlands, where the price of energy and the cost of RES produced energy are comparable has this system been permitted but still only for limited capacities in the order of 10kVA (except from Italy where the upper limit is equal to 200kW) (HELAPCO, 2013).



Figure 57: Scematic of Net Metering and FIT System (HELAPCO, 2013; Windchallenge, 2013)

Truly the benefits of the Net Metering system have been realized by the MEECC which has given the green light for its initiation through the very recent passing of law 4203/2013 in October 2013 (Econews, 2013). This law has allowed for the installation of photovoltaics and small wind turbines (nonetheless also a separate study program regarding SWT implementation aspects has been issued which until its conclusion in June 2014 binds the installation of these machines) for such configurations has been also issued and the supply of their produced energy into the Network grid without imposing a limitation on the installed power capacity or the location of installation (rooftops or ground level). The deduction of produced from supplied energy takes place every measurement cycle issued by the utility company, which in Greece is usually equal to four months, and also as issued by the according law no compensation is provided in the case of surplus of produced energy. In order to not increase the deficit of LAGIE no compensation is provided for energy surplus by the state but the option of a provided compensation from the utility company is left open. Finally the most important aspect of this law regarding small wind turbines is the fact that according energy production stations are exempted from any kind of suspension of the licensing process (Hellenic Republic, 2013).

Although this initiative has set the grounds for the bypass of market distortions and inefficiencies, yet a number of parameters are left to be decided. Most importantly the details regarding the implementation of this measure are left in the discretion of the MEECC to be decided upon Ministerial decision (after the consideration of RAE's and HEDNO's opinions) and thus the success or failure of the measure has become a matter of political will. By considering that the previous law 3851/2010 (which essentially issued the separate FIT system for SWT being also based upon analogous political will) was highly unsuccessful, it follows that following of regulations uncertainties logically will arise which could potentially increase the risk perception of investors regarding financial losses resulting in unwillingness to proceed to the implementation of this technology. Furthermore since now the specific rules of Net Metering have not been issued by law and can be changed by the according Minister, a new uncertainty parameter is introduced.

The Net Metering system for small wind turbines does not offer payback times as low as the FIT system nor does it yield the potential income that could be obtained by the latter. With the Net Metering system the monetary value of produced RES energy becomes equal to the Supplier's (in almost all cases PPC) issued retail (end-user) energy price for households which, if all charges are added, is equal to $0,14073 \in /kWh$ (Europe's Energy Portal, 2013) thus undergoing a reduction of 43,7% if the according FIT price of $250 \notin /kWh$ is considered. With this high price reduction the calculations of Chapter 3 are no longer valid and the projected payback time may potentially be equal to the entire lifetime of the turbine, if all other parameters are kept constant. Thus other incentives must be provided if this measure is to be promoted with the most important being the lowering of connection costs. As explained in Chapter 4 connections costs may reach 8,3% to 24% of total investment costs and thus can and must be reduced for the promotion of this policy. Also a potential compensation for surplus energy could further increase the attractiveness of such an investment.

Furthermore the Network/System may not be capable at the moment to economically sustain the growing penetration of Net Metering producers (especially if PV producers are added) since issues regarding the stability, adequacy, efficiency of infrastructure equipment and of the Network/System itself maybe encountered. These problems may be created since the funds for the operation and maintenance of the Network/System are obtained from consumers, based on the supplied energy for consumption by Utility companies or consumer energy Inflow. Since through the Net Metering System the net outcome of Outflow minus Inflow is to be used for the calculation of electricity bills, an "accounting" result of zero energy supplied from utility companies is created at the end of each measurement cycle (four months). This "accounting" result will not reflect on the true energy transactions which strain the grid infrastructure and thus the cost of its maintenance will be divided to a diminishing number of consumers. This may potentially increase the cost of energy for non-Net Metering RET users which also could lead to the increase of LAGIE's RES funding mechanism deficit for the same reasons as explained in previous chapters (Association of Photovoltaic Energy Producers, 2013).

For these reasons, the following immediate measures and clarifications are also required if Net Metering is to be promoted and contribute to the installation of SWT (Association of Photovoltaic Energy Producers, 2012; HELAPCO, 2013; Wikipedia, 2013):

- 1. Immediate issuing of operation details by law to reduce the perceived uncertainties of potential change of regulations by future Ministerial Decisions
- 2. Limiting of permitted installed power capacity to maximum 20 kW to avoid future distortions of the market created by the penetration of an irrationally high number of large power output SWT . The

limit of 20kW is also chosen based on the fact that the Hellenic Government already exempts turbines under such nominal power from a substantial number of required licenses. This will accelerate the overall procedures of the above recommendation.

- 3. Allowing for the deduction of energy to be issued by meters which are located on different locations than that of the installed system. In essence this measure will give the opportunity for consumers whose households are located in low wind potential areas to either install SWT on rented land or different property but still enjoy the economic benefits of Net Metering as explained above
- 4. Allowing for use of Net Metering RES energy production systems by third users (other than the potential owner). The leasing of household installed small wind turbines by business groups will further the implementation of SWT projects and can increase funding opportunities for potential consumers or even provide potential income.
- 5. The number of allowed small wind turbines to be used under the Net Metering policy must be based on the number of different consumption meters and not per building. Hence in multistory buildings the number of allowed SWT may equal the number of residents and more turbines can be potentially installed as long as adequate measurements allow for such configurations without compromising the energy extraction per turbine.
- 6. Issuing of surplus energy compensations from the utility company when energy is directed into the Network at every measurement cycle or issuance of annual kWh credit in order for produced energy to be "stored" into the grid and be used later. The price of the surplus in the first case is to be based on the retail price of electricity currently in the country while in the latter no compensation could be issued.

With the successful issuing of the above recommendations this measure can allow for the immediate installation of SWT and provide much needed funds for companies which are oriented toward On grid systems. Although Net Metering will bypass the inefficiencies of the FIT system in Greece and the "frozen" licensing procedures, thus buying valuable time for much needed reforms, it should not directly replace the entire scheme of guaranteed prices since the latter clearly consists of the most economically attractive option for potential investors especially in the upper range of nominal power turbines (20-50 kW). As such Net Metering Systems and FIT Systems must be allowed to co-exist and be co-implemented on the same installation areas. Following this very important near term measure, medium term actions addressing the predominant barrier must take place.

Medium term actions must address the predominant barrier's elements from a micro level approach (thus more directly) and have as an overall goal the finalization of the existing licensing procedures put on hold and the gradual allowance of installation of SWT under the FIT system as issued by law 3851/2010. As described earlier the introduction of the Net Metering system may provide with the required time period during which a number of necessary reforms can take place. In order to succeed with this approach it is imperative that the actions proposed are focused towards achieving three main tasks:
- Reducing the deficit of LAGIE's RES funding mechanism to sustainable levels while reflecting the true benefits of RES in general and SWT in particular over conventional energy production methods
- Creating a development plan which will allow the gradual and controlled installation of small wind turbines
- Reducing the amount of cost and time required for the licensing procedure regarding the FIT system

More analytically, as described in previous parts the inability to implement this technology is interlinked with the economic inability of the State to fund producers, through the issued by law FIT system, due to the monetary deficit of the according mechanism. It is logical that a potential allowance of a number of machines to be installed would most likely cause the further inflation of the deficit or the failure of the investments, both leading eventually to the further destabilization of the total energy market or the characterization of this technology as "bad" investment. Furthermore it was proved in Chapter 4 that the deficit itself remains a function of the inherently incorrect way of calculation of the funds acquired by the special RES levy (ETMEAP) by electricity consumers which indirectly promotes and funds conventional energy production methods. Thus in order to overcome the overall barrier two essential actions must be taken:

- 1. Gradual replacement of the Weighted Average Variable Cost (described in Chapter 4) of conventional thermal power plants for the calculation of the ETMEAP (Hellenic Republic, 2013) by a different parameter of increased value to accelerate the coverage of the deficit. In such a manner the funds acquired by Suppliers (PPC) will increase thus permitting the stabilization of consumerpaid-RES-funding ETMEAP allowing for the decharacterization of RET and SWT in particular as expensive commodities solely existing thanks to consumer provided subsidies
- 2. Gradual return of indirect funds acquired by electricity supplying companies due to the distorted manner of calculating ETMEAP (described in Chapter 4-Market Distortions). As proposed by HWEA the remaining accumulated debt must be passed on to the competitive part of suppliers invoices and be recovered by the end of 2016 through a fee that is less than 4 €/MWh or until the end of 2020, a fee of less than 2 €/MWh (HWEA, 2013). By this measure a significant part of the deficit will be covered

Both actions require significant cooperation of Governmental and non-Governmental stakeholders and can potentially provide with a quick solution to the core problem faced currently in Greece regarding RES funding via the issued guaranteed prices. Although the Supplying companies are most certainly to object to such a measure, the according market Operators must ensure the correct implementation of a proven just measure. With the success of rationalization of the deficit, the FIT scheme issued by law 3851/2010 can be eventually applied for the case of small wind turbines thus further contributing to their growth, especially for larger scale turbines of 50 kW, as the superior investment scheme.

Alongside the measures targeting to correct the economic market inefficiencies, a plan that may even exceed the medium term time limits as described previously is imperative to be issued regarding the development of small wind turbines and RET in general. HWEA has already called for the activation of the National Energy Planning Committee (based on the 2050 Energy Roadmap presented in March 2012) and has proposed the cooperation with MEECC and all market players in order to establish a Working Group for the issuance of an according plan. Although such cooperation has yet to be established and currently no such plan exists regarding the technology of SWT which will ensure that the occurred mismanagement during the deployment of photovoltaics will not be repeated, an encouraging step towards the correct direction has been taken. The MEECC has indeed included in the newly established law 4203/2013Paragraph 4 which concerns the initiation of a specific Development Program for small wind turbines to be issued upon a decision of the Minister until the 30/6/2014 without although giving in depth information regarding its contents apart from the fact that it will be based on a techno economic analysis which will explore the macroeconomic benefits and effects on the costs of electricity from the optimum exploitation of the wind potential as well as include safety and electrical energy absorption from local grid aspects.

If the Small Wind Turbine Development Program is to succeed and be actually implemented it is imperative that all related inefficiencies identified in previous legislative acts as well as technical and social issues are thoroughly examined. By taking into account that among others actual test sites do not exist, tests under real conditions have not been performed, sociopolitical issues have not yet been identified for this technology in the different parts of the country, standards and regulations specifically for SWT as well as wind measurements close to the ground level do not exist and based on the relative roadmap issued by NREL, it is the authors opinion that a complete study should be expanded in a time frame which will exceed the proposed deadline issued by the Ministry by the amount of time required until all different parameters mentioned above have been properly and completely assessed.

During this time frame, by the issuing of the Net Metering system, already a significant number of small wind turbines will have been installed and thus a valuable amount of knowledge and on-the-field experience will have been gathered regarding problems of technical and non-technical nature which can be integrated to the FIT system deployment plan. Apart from the acquired knowledge of already implemented turbines under the Net Metering system, technical studies from according institutions such as CRES will be also performed which will specify and compare the efficiencies of different types of machines existing in the Hellenic Market, resulting in an overall energy yield of SWT. As such, accurate recommendations could be provided from suppliers, installers, policymakers and stakeholders in general regarding safety, building integration or installation of the turbine, non-technical and economic matters in order to avoid generalizations in the plan which may result in the incorrect, potentially hazardous and of lower economic profit yield operation of the machines. Especially important is the fact that the predicting capability of existing profit or cost of energy calculators or methods will have improved and could be included in a plan which would ensure the maximization of profits per installed area.

It should be noted that with the allowance of the Net Metering system and the in parallel optimization of a future deployment plan regarding SWT under the FIT scheme in different regions of Greece, the postponing of the issuance of the ministerial decision as described in law 4103/2013 will not essentially put on hold small wind turbines as a growing market as before but rather provide with more time for the in detail investigation of related issues, overall re-organization of the entire sector and issuance of a specific plan that will ensure the future steady growth of the sector and avoidance of possible uncertainties which could result in an similar to Photovoltaic sector "bubble".

Regarding the development plan, a detailed calculation must be also performed which will take into account the local electricity grid capacity coverage/saturation (in order to avoid energy overproduction which cannot be absorbed) and yearly limits of power capacity installation per area must be issued by involving the according regulatory instruments and Operators. It is particularly important that local "overcrowding" is avoided since due to the technical nature of SWT, with more machines installed at close proximity to one another (as presented in Chapter 2) energy extraction and thus economic yields will be lower while noise levels will increase resulting in larger investment payback times and more complaints and social opposition accordingly.

The last medium term action proposed for overcoming the predominant barrier is the rationalization of the licensing procedure both in terms of relative cost and time regarding the FIT system. As defined in previous chapters the fact that licensing procedure costs can increase the overall expenditures of an investment directly (amount required for the issuance of the license of production itself as well as connection costs and other parameters) as well as indirectly (costs associated with time delays and depreciation of capital and equipment), hinder the implementation of SWT. The lowering of related costs thus is of high importance for their successful deployment. As identified in Chapter 4 the overall costs of acquiring all required licenses and issue an energy selling contract may even reach as high as 24% of the total investment costs in the case of a 50 kW turbine. It is logical that this percentage must be significantly lowered or be partially covered by financing schemes or other type of economic exemptions.

Also since the re-introduction of small wind turbines within a reformed energy sector where the FIT system will be allowed, having solved a number of important obstacles and having previously determined the mentioned deployment plan, it is natural that a licensing system which will ensure steady, unobstructed and most importantly without delays connection to the grid procedures will have to be issued by the MEECC and the governmental policy makers of the country. These procedures must be binding for all actors and most importantly for the Network Operator and RES producer including accurately determined, rational time periods within each party must be obligated by law to finalize their according tasks. To avoid the previous catastrophic inefficiencies and complications of the system which essentially never allowed for the implementation of small wind turbines in the country the Ministry must ensure that failure to comply with the regulations will have direct consequences which will range from economic penalties to the decline of the connection request. The political will to follow the existing regulations and directly apply pressure to any non-conforming party and especially the Operator responsible for the evaluation of requests and granting of licenses, is thus imperative.

5.3 Issuing Standards and supporting regulations

In previous Chapters it was identified that Greece does not possess of National Standards or Quality Assurance codes and criteria which specify the prerequisites regarding the different stages of small wind turbine installations specifically for different areas of the country, nor has it adopted existing foreign international Standards which could help cover this technical and legislative gap. Furthermore, the previous presented facts have proven the importance of the existence of such codes and the according compliance of manufacturers, suppliers, consumers and all relevant stakeholders to them, since they are interrelated to the establishment of consumer trust and prevention of accidents and poor quality products. As such implementation parameters such as imported machine characteristics and suitability per area of installation, urban spatial deployment planning aspects, and quality control of all relevant actions performed, ranging from the purchase of a turbine and validation of manufacturer claimed technical characteristics to the final stages of installation and maintenance by trained personnel, are left to the discretion of SWT Suppliers which may choose to certify their services by an external Third party Inspection-Certification Body (such as <u>TUV HELLAS</u>) or not provide with any assurances whatsoever.

The significance of issuing National Standards or adopting an existing SWT specific standardization code which will cover all aforementioned areas is critical for overcoming a number of technical and nontechnical barriers. By taking into account the fact that small wind turbines are essentially a "novel" technology, when comparing the numbers of machines installed and the previously described attitude of Government stakeholders towards it with other competing RET, the need for concrete guidance through Standardization is even more pronounced if mistakes are to be avoided. Finally by considering that the MEECC has already set the basis for the immediate implementation of SWT under the Net Metering System the adoption of relative Standards and certifications is ever more urgent. Based on the above argumentation as well as the information provided by Chapter 4 the issuance of relevant National regulations is considered to be both an action of near and medium term nature.

In the near term phase the Hellenic Government must immediately adopt a relative existing Standardization code which will cover the entire power output range of small wind turbines. By taking as an example Germany and Spain, two European countries where National Standards do not exist but other Standards have been adopted, Greece must include in its legislation the requirement that all imported and implemented SWT must comply to the (mentioned in Chapter 4) AWEA Standard 9.1 -2009 and BWEA standard on small wind turbine performance and safety. Based on these Standards all SWT already imported in the country must be evaluated by the conduction of tests which follow the guidelines of the according Standards and characterized based on their Power Curve, sound emission, fatigue and stress test results. Eventually the ones fulfilling the criteria must be certified by the Hellenic Government or by a specified authority which will ensure their manufacturing quality. Any machines which fail to comply with these quality standards will not receive certification and will be not allowed to be installed thus ensuring a uniform level of product quality in the Hellenic market.

Both Standards also include norms regarding two important aspects of SWT operation which if properly defined simultaneously address economic and social barriers as well. These two aspects are the emitted Sound levels from the turbine and site specific wind velocity measurement based on which the techno-economic study of the Consulting/Supplier Company will be based on. The methodology, instruments and certification procedures are included in the guidelines of the according Standards and coupled with the existing laws and regulations of the country can essentially set criteria based on which the evaluation of the suitability of different SWT types regarding these matters can be performed. Especially regarding noise emissions, until the issuing of (defined by law) small wind turbine specific sound pressure limits and according regulations, the existing regulations regarding sound emissions from electrical energy production systems described in Chapter 3 coupled with the standardization limits will suffice.

Apart from solely evaluating the imported turbine manufacturing characteristics, both aforementioned Standards must provide with a set of guidelines for the installation procedure and O&M matters as well. Such matters may include Standards ranging from the excavation procedures, towers, wires, foundation, anchors, cables, and relative infrastructure to be used to the necessary equipment and safety gear utilized by constructors and workers during the installation and use of machinery (such as lifting cranes). If these Standards do not explicitly state rules for the all of the above, the state must immediately proceed to either allow only certified trained personnel to perform installation or enforce Supplier companies to have their own installation crews be certified by Third party Inspection-Certification Body which will assess them based on existing norms. As such apart from ensuring the quality of the turbine itself, Suppliers must provide quality certified installation services through properly trained and certified personnel thus solving the potential problem of poorly operating quality machinery due to incorrect installation methods and hiring unqualified and personnel which can potentially put in danger themselves or the property owners.

The adoption of existing Standards will provide the opportunity for Greece to immediately implement small wind turbines in a safe, certified manner and associate these technological products will high quality. Nonetheless Greece should further the efforts for eventually adopting the international and quite demanding both in compliance requirements and economic terms IEC 61400-2 Standard. When the market is deemed to be more mature and established, with the overall RES market having been rationalized and the FIT system being re-implemented, the integration of the IEC 61400-2 in the existing Standardization Codes could further increase the overall quality standards of the entire SWT market. If the adoption of the entire IEC Standard is still prohibiting, the creation of a "tailored" Hellenic Standard, based on the above but with alterations to fit national requirements determined through acquired experience and performed testing results, could also provide with a viable option. Eventually through this initiative, a National Standard or Certification Scheme, similar to the British *Microgeneration Certification Scheme (MSC)*, which will define and develop protocols regarding safety, building integration and noise, could be established. Both of these actions require a time period which will exceed the near term time frame and thus should be considered as medium term goals.

In order to support the introduction of SWT Standards and compliance of Suppliers to them, regulatory reforms must take place both in near and medium terms. As such specific regulations must provide a frame which will ensure the full adoption of Standards and Government or separate non-Governmental Stakeholder control over the certification of turbines. In essence the Government must proceed to legislative acts which will include in their core the compliance to Standard requirements. For example, a future law which will include the limits of small wind turbine noise emissions must be based upon the permitted limits of existing standardizations. In that manner the compliance to international standards will be required by law and will be mandatory, thus binding all stakeholders. This action can be performed over a medium term basis in order for future Standardization changes until the market is mature and a concrete Standardization Code is adopted to be included in the according legislative acts.

Apart from the above other crucial issues, complementary to standards, must be determined by the state. One of these is the determination of regulations regarding the urban planning and deployment of SWT which is currently not included in Greek legislation. If the turbines are recognized in the spatial development plan and deployment plans respect the vision other stakeholders have about the location of installation, significant legal, technical and social barriers are countered simultaneously. As determined in Chapter 4, the lack of specific urban planning regulations may be the cause for potentially hazardous installations or the failure of investments since misinterpretations could enhance unjustified local opposition. Especially considering the proximity of installation to residences and the previously mentioned social barriers, a well-defined legislation which will cover every aspect of the above matters will not only adequately address the mentioned barriers but will also facilitate the introduction of small wind turbines.

5.4 Providing Economic Incentives and expanding the Market

Greece currently does not possess of a small wind turbine manufacturing industry and as such imports turbines from abroad. As described in Chapter 4 these imported turbines come at a high retail price, which along with the required infrastructure and licensing procedures result in overall high upfront project costs. Also it was presented that this capital intensive technology due to the fact that is still immature is characterized by price deviations between different models (the range of available turbine power outputs creates a range of upfront costs which can vary from less than $1000 \in$ to more than $240000 \in$), in general may be more expensive per installed kw than other competing RET and investment-wise result in higher payback time thus being less attractive to potential investors. Furthermore due to the economic situation of the country the limited financing provided by the Government and banks via loaning, do not permit for investments or limit investors to fund such projects directly by equity, on the risk of facing grave economic losses. It is obvious that if SWT are to be established in the Hellenic RES market and expand in the future, Governmental or non-Governmental financing strategies and economic incentives must be followed and issued accordingly in order to create opportunities for less risky and economically interesting and profitable investments to be made.

No near term action can address the issue of high upfront cost at a micro level, since all turbines are imported from abroad and turbine costs due to technological immaturity and low production numbers are still high. Nonetheless actions may be taken at a macro level in order to provide options which reduce the risk associated with high upfront costs and high payback time. As explained previously small wind turbines installed under the Net metering policy can essentially be considered as an energy saving or energy efficiency investment. In the US, where this policy has been used extensively for the majority of SWT, two main financing Strategies for energy efficiency projects have been identified by studies conducted by the EDF (Energy Defense Fund) in order to overcome previously mentioned economic barriers. Although many economic differences between the US and EU exist, since the same policy is to be implemented regarding a technology which globally faces almost the same economic barriers (American Wind Energy Association, 2010; Environmental Defence Fund, 2011; European Wind Energy Association, 2009; World Wind Energy Association, 2013), significant analogies can be drawn and potentially almost the same solutions can be applied in the case of Net Metering in Greece and also be expanded for the FIT system as well.

In EDF's 2011 report "Show Me the Money - Energy Efficiency Financing Barriers and Opportunities" two main approaches are provided for the determination of financing for energy projects the Internal Financing Strategies and External Financing Strategies. The approaches differ based on the origin of the funding. In the first case the institution or household consumer utilizes existing financial resources while in the second case funds are provided by third party capital.

Internal Financing Strategies provide an opportunity for consumers but also for institutions such as schools, hospitals, universities and private companies which possess budgetary flexibility but are unsure on implementing relevant technologies due to associated risks, to proceed to investments which will recoup electricity cost saving over a number of years without having to pay for additional debt interest (Environmental Defence Fund, 2011) or wait for additional funding options to arrive. Considering the funding limitations of the Hellenic Government due to the current economic status of Greece, internal financing strategies can be considered as logical options. Such strategies have in their core the reduction of perceived risk as well as the overall estimation of an investment which is not solely assessed based on the payback time. As such the cooperation with *Energy Service Companies* (ESCOs) is considered of primary importance for achieving the above.

ESCOs are commercially energy service firms which offer a range of techno-economic solutions for customers seeking to improve their energy efficiency. Essentially they offer solutions based on client requirements and undertake the task of installing new or replacing aging, high maintenance and costly engineering equipment while verifying the energy and costs savings earned over the time period issued by contract, which will eventually pay back for the initial investment (Environmental Defence Fund, 2011). Although ESCOs are more oriented towards offering contracts to larger groups rather than individuals, upgrading energy-wise entire multistory buildings is common practice. In this sense household owners in such buildings who wish to install small wind turbines on rooftop of ground area can benefit from ESCOs by including in the overall building upgrade contract the installation of a turbine for energy saving reasons. By cooperating with ESCOs the home owner or group essentially achieves a significant reduction of risk in their investment since the ESCO that installs the improvements contractually guarantees a combination of savings on energy consumption and improved system performance, or both over the contract period. In its turn the ESCO which undertake the task, does not risk own funds since the project is funded by client capital.

Regarding the implementation of RET in industrial facilities, self-financing strategies focusing in the deployment of internal funds may provide energy performance and overall benefits even without the use of ESCOs. By redefining financial requirements and focusing away from investments which are strictly considered based on their small payback period regardless of their long time saving potential, companies can take into account other economic parameters in order to maximize their profits (this concept will be also analyzed further regarding CSR driven investments). As such, apart from the payback time, the NPV can be utilized for the characterization of investments resulting in to projects which despite their higher payback time, will yield significant NPVs. This approach is fitting for SWT, especially when installed under a FIT scheme as shown in Chapter 3. By following such strategies, companies with industrial facilities may even proceed to the creation of internal capital pools dedicated to providing with the necessary funding for such projects, which in the future will provide with high economic yields from energy saving (Net Metering) or direct energy producing (FIT).

A medium term self-financing approach for the promotion of RET could be the creation of institutionally owned capital fund pools or *Green Revolving Funds* (GRFs) from which money could be lent for the completion of a relative energy upgrading project within different parts of the institution. With annual earnings the capital fund would be gradually replenished and different members could borrow to proceed to their own investments. This concept is particularly interesting for private hospitals, schools and universities and has been growing rapidly in the US over recent years, especially regarding the latter category (Environmental Defence Fund, 2011). For example in schools or universities, funds are raised by central administrative and departmental budgets, student fees, pre-existing efficiency savings and utility rebates, alumni donations, and/or endowment funds over five year periods or more. The funds operate and are managed by the university, with loans issued to university departments or campus groups (Wikipedia, 2013). In Greece this measure could be applied in the former mentioned categories but not to state owned institutions which form the high majority. Nonetheless local municipalities, which enjoy a level of financial autonomy from the Government, could proceed to the creation of such funds granted that issues of

corruption are addressed beforehand. Furthermore expanded capital fund pools from different municipalities forming partnerships could be combined, with resources being available to all of them. With this solution, essentially the limitations induce by the lack of institutional or local municipality wealth will not prevent the installation of RET where required.

Considering the country specific aspects of SWT implementation, it is fact that for a significant number of small scale investors (especially household owners) internal financing is not an option when other funding priorities exist, especially amidst an economic crisis environment. In such cases External Financing Strategies can provide solutions in the determination of required funds. This kind of financing can be predominantly provided by Government actions but also, as identified for the US, by third party investment funds and special banking loans as well, thus bypassing the need for legislative reforms or other state intervention.

The Hellenic government can directly provide funds through the issuing of specified investment laws to investors who fulfill specific criteria. Although such legislation acts currently do not exist specifically for small wind turbines, laws 3299/2004, 3908/2011 and 4146/2013 support general investment projects for new and existing businesses by providing incentives in the form of tax exemptions and granting and leasing subsidies. Specifically under the later law 4126/2013, very small and small businesses which are interested in investments of at least $100000 \in$ accordingly regarding energy production systems apart from photovoltaics can receive the following subsidy forms (StartUp Greece, 2013):

- 1. **Tax exemptions:** exemption from payment of income tax on pre-tax profits obtained by the total of business activities. The amount of the tax exemption is calculated as a percentage of the value of assisted costs of the investment project or the value of new machinery and equipment acquired
- 2. **Grants**: funds provided free of charge from the State in order to cover parts of the investment project costs, determined as a percentage of the latter
- 3. Leasing Subsidy: coverage of leasing installments, by the State Board, regarding the acquisition of new machinery and equipment, determined as a percentage of the value of these acquisition installments.

By taking account the above, investors contemplating an investment in small wind turbines in the range of 20-50 kW can be integrated into the new Development Law 4146/2013 granted that their investment is at least over 100000€. According to PK Consulting Group, grant rates can reach up to 50% depending on the geographic area in which the investment is made while the self-funding capital required is only equal to 25% of the total investment while the remainder of the funding scheme may be covered by medium-long term(5-15 years) bank borrowing (PK Consulting Group, 2013). The fact that this investment law subsidizes such activities in the form of a money supply grant/donation (whereas before previous laws provided only tax exemptions), further underlines its significance and its potential as a policy measure to actively promote SWT. Although this is a considerable step towards the promotion of upper range power output small wind turbines, it is imperative that according investment opportunities described by law are to be provided in the near term future by the Government regarding smaller output machines. Thus of

smaller economic scale but of equal importance investments towards the end goal of penetration of this technology can be achieved, boosting this particular RET market.

Apart from legislative acts, government-backed funding programs similar to the previously mentioned in Chapter 4 "Energy Efficiency at Household Buildings" which can guarantee to protect against investor default risk but also provide with incentives both towards consumers and banks alike in order to increase loan demand and allow the latter to proceed to favorable terms loan issuances for the implementation of small wind turbines, must be issued. Already such *Soft Loans* which would include below the market rate of interest, longer repayment periods and interest breaks within the repayment period or other advantages facilitating in this way the access of businesses to funding, and reducing the total borrowing cost (General Secretariat for Industry, 2012) exist for a broad category of investments regarding "Green Infrastructure".

More specifically the Fund for Entrepreneurship of the ETEAN S.A.-Hellenic Fund for Entrepreneurship and Development S.A. and the National Bank of Greece have issued since 2012 a relative action including a capital amount reaching 150 million \in from which loans between 50000 \in to 500000 \in can be provided with a duration from 5 to 10 years with a possibility of an interest-bearing grace period up to 2 years and a stable during the entire period of loan and equal to 3.67% annual interest rate (General Secretariat for Industry, 2012). Although this action is considered very positive for the promotion of RET in general including SWT, further monetary lending actions specifically tailored for the particular technology and its associated techno economic characteristics must be issued in the future. In that sense "Small Wind Turbine Soft Loans" could eventually be provided by banks and government alike It is worth noting that the adoption or creation of Standardization procedures and certification of turbines as well as local wind potential measurements will further decrease the uncertainty associated with such investments and as such the risk of loan defaults due to unexpectedly small energy yields and economic returns (Georgakopoulos T. , 2011). This fact will contribute significantly towards the facilitation of loan issuances from banks. Since this is not the case currently, this action should be considered of medium term.

External funding options described up till now have as a common parameter Government intervention. Nonetheless considering the economic situation of the country which currently is struggling to succeed in fulfilling its fiscal goals and more particularly in achieving a primary surplus in order to ensure the required monetary support from its lenders, it follows that due to other priorities few funds can be diverted at the moment towards novel small scale energy producing technologies. For this reason models which do not require state participation or government policy changes and can create agreements between investment funds, household owners and electrical energy Suppliers in order to create investor access to upfront capital, are required as a near term action. Such models have been identified for the USA market and include the Energy Services Agreement (ESA) and Managed Energy Services Agreement (MESA) models.

In the ESA model an investment fund acts as an intermediary between the household owner and the service provider who is the RET supplier/installer company and develops two separate contracts between these parties. These contracts are the ESA (Energy Services Agreement) signed between the fund and the household owner and the ESPC (Efficiency Services Performance Contract) signed between the fund and the service provider. Through these contracts the investment fund is responsible for the funding of the project but simultaneously owns all of the installed equipment and energy producing assets during the

length of the agreement. More specifically through the ESA, project funding becomes the responsibility of the fund while a specific regular and scaling with energy savings service charge (defined as a cost per unit of avoided energy which is equal to the owner's normal energy costs) is agreed to be paid by the owner to the fund, which eventually pays off for the capital investment as well as providing a return to the fund's partners and lenders. Through the ESPC, the agreement details regarding the engineering, procurement, construction and O&M aspects of the project are defined as well as performance guarantees are included..

In the MESA model the core concept remains the same with the only deference being identified on the agreement between the investment fund and building owner. In this case the owner is not charged with a service charge but the investment fund assumes the role the intermediary between the owner and the utility, paying the building owner's on-going utility bill directly and charging the building owner a fixed monthly fee equal to location-parameter-adjusted building's historical energy rates. As such the investment fund generates revenue by capturing the difference between the building's initial energy costs and its decreasing energy costs as the building is made more efficient over time (Environmental Defence Fund, 2011).

Via the ESA and MESA models, presented in Figure 58 and Figure 59, the household owner avoids all upfront and development costs and is charged only for a predefined cost per unit of avoided energy or fixed monthly fee which guarantees the paying of less money per month for energy than before the issuing of the according agreement.



Figure 58: ESA Model Structure (Environmental Defence Fund, 2011)



Figure 59: MESA Model Structure (Environmental Defence Fund, 2011)

Solely providing the above economic incentives in a small and underdeveloped market will not succeed in truly establishing this technology in the long run. Actions which will focus on expanding the market are required to run in parallel in order for the small wind turbine technological brand to mature. Such actions must work both in a micro and macro level approach but due to the significant time requirements, they should be considered as medium term actions.

Essentially the predominant measures to expand the market of SWT can be considered to be:

- Interconnection of the Islands with the Mainland System and creation of Smart Grids
- Research and Development
- Establishment of domestic industry (manufacturing and maintenance)

In Chapter 3 it was described that the highest wind potential in Greece exists in the Islands (Figure 44) which are currently not connected to the mainland grid. Although a goal has been set in the National Renewable Action Plan for their gradual interconnection to the mainland grid, which will result in decommissioning of the local oil-fired plants saving associated costs from the national economy, serving better power quality to consumers and further penetration of RET in the energy mix, no action has been performed regarding the matter. As identified by the research conducted over this thesis, a number of Offgrid systems have been installed in these areas. Nonetheless since the majority of islanders do not live in remote areas, On-grid applications must be boosted in order to successfully promote this technology in the broad public. As such the opportunity of producing energy at household level and either consuming it and supplying excess electricity to the mainland (Net Metering) or directly producing electricity and supplying it to the mainland (FIT), along with the adoption or the six regulatory remarks concerning Net Metering described previously, would greatly expand the market towards these high potential energy areas. This near term action must be performed as soon as possible and in cases of small islands whose connection may be difficult or not cost-effective, autonomous systems must be deployed. Following the interconnection of the islands, the medium term action of creating smart grid systems must be prioritized. Since currently the necessary infrastructure does not exist, time can work in favor for the according authorities since the conduction of pilot programs can be realized and the conclusions can be applied to the islands where the existence of a large number of small RET an operate nominally under such conditions.

With the gradual introduction of SWT systems on On-Grid applications in the manner described previously, the role of Research and Development will become increasingly important in the effort of expanding the market. As described in previous chapters, up until now the possible conduction of R&D has befallen on CRES and universities since manufacturing industries do not exist and as such it has remained in a somewhat restrained "academic" level. Also since the technology has not been essentially implemented apart from Off-grid applications for which little to none information is provided publicly, issues from real operating conditions have not been properly identified, quantified or addressed by governmental institutions or any other than the supplying companies which are also responsible for the installation and O&M of their machines. Since these companies deal with the import and not construction of turbines they do not engage in R&D and as such are constrained to the characteristics of the turbines as provided by the manufacturing companies, thus being unable to perform alterations which could increase performance under the specific Hellenic environment.

In order to truly establish R&D in the country regarding this technology, specific governmental and non-governmental institutions must be issued and equipped properly in order to conduct investigations with a focus on the commercial capabilities of these machines. As a first measure CRES must create a specific department for such studies which will collaborate closely with both the industry and other stakeholders, especially in the phase of adoption of foreign Standards and testing of imported wind turbine models in Greece. Once the certification of machines which will fulfill adopted criteria is completed, research can be focused on improving implementation aspects such as installation and building integration for which importing companies are not restrained by manufacturing companies and can make alterations upon. With the gradual adoption of SWT the need for the accurate establishment of actual output power, overall energy potential, types of failure, actual noise levels and noise perception of these machines on different locations in Greece as well as the creation of a National Database which will include data for all of the above, will be imminent. As such testing could be conducted in actual test sites in the built environment which despite their possible safety related restrictions could provide with more realistic results. The research conducted in these test facilities will thus have the opportunity to address significant technical issues as well as socio-economic obstacles as they arise from the actual implementation of SWT in Greece. Also they will be able to actively participate in the development of noise, safety and installation norms which in their turn can be incorporated in the foreign adopted Standards and contribute to the creation of a National Standard. As a medium term action thus, the issuing of a general Hellenic R&D program must be considered which will aim at addressing issues in order for the technology to be able to expand widely.

The last proposed action for the expansion of the small wind turbine market in Greece is directly connected to the establishment of R&D and by definition is considered to be a medium term action. The creation of a manufacturing industry which will consist of more than one (pioneering) company and be able eventually to construct high quality small wind turbines or specific parts of them requires Government support, private initiative, adequate funding, pre-existing know-how and an already established market⁺ parameters which currently are missing from the country. Since small wind turbines consist of products which do not require the vast amount of materials or electromechanical parts as their large wind turbine counterparts, their construction could be assumed to be possible without the need for extremely high investments on industrial equipment. Furthermore, if all of the proposed measures and actions have been issued, a significant number of the above described parameters will have been addressed to a sufficient extent, thus allowing for the design and construction of competitive products to imported turbines. Considering the potential benefits of the establishment of such an industry in Greece over the economic growth of the country, direct and indirect to the technological branch creation of employment positions and redirection of funds (now spent on imports) to an established domestic market, the feat seems worthwhile provided the existence of proper infrastructure on all levels regarding SWT manufacturing.

5.5 Promoting Social Corporate Responcibility through SWT adoption

As it has been described in Chapter 3, embracing the promotion of Sustainability as part of a CSR advertising policy focused on adopting measures to provide with eco-friendlier products and services, apart from being ethically correct can also project a developed corporate social profile which can result in financial benefits for the investing company (Orlitzky, Schmid, & Rynes, 2003). In an effort to avoid the establishment of the association in consumer minds of "high carbon footprint" with "negative corporate image" and its direct or indirect effects on reduced economic, an increasing number of companies put

significant effort into reducing their carbon footprint and CO_2 emissions by adopting measures including recycling of materials, reduction of water use and reduction of cost of energy and energy consumption. Regarding the latter category, such measures are the replacement of high energy consuming fluorescent lamps, thermal energy upgrading of buildings and adoption of small scale RES energy producing systems such as Photovoltaic panels or small wind turbines.

Regarding the EU, a trend firmly promoting the grading of companies based on CSR related parameters and publications of according corporate actions, has been established during the recent years. The pinnacle of these efforts is a European Commission Directive (to be voted in the next six months) which will consist the publication of information regarding CSR oriented social and environmental corporate actions, mandatory. By considering that in EU countries only 2500 out of 42000 corporations or approximately 6% publish such information officially on an annual basis, the European Commission, by following the example of Denmark and Norway, has decided that the increase of such publicly accessed data will contribute significantly in helping consumers, local communities and companies alike to assess and manage according social and environmental issues related to corporate operation more accurately and successfully. This measure, which initially will only regard companies with over 500 employees (approximately more than 14000 companies in the EU) but eventually include smaller companies as well depending on its potential success, will attempt to set common grounds for the assessment of European companies under the same legislative framework a feat which will have to face different and often contradictory policies per each country.

Already a number of Hellenic corporations from different fields have invested on CSR following the general EU trend. It is worth mentioning the significant achievements of the Hellenic corporation Mytilinaios Group which in 2012 received certification from the *Global Reporting Initiative* (GRI) by complying with the GRI-G3 Standard and was awarded the 1st and 9th place among all Greek and International corporations which participated in Bloomberg's international Environmental Society Governance (ESG) data service which covers companies reporting on their Environmental, Society and Governance performance (Mytilineos Group, 2012). The group has been consider as a leader in the particular field since it has been publicly active in CSR actions related to Climate Change and protection of the Environment aspects over the last four (4) years.

In the 2009 research conducted by the Hellenic Network for Corporate Social Responsibility in collaboration with the Canadian pollster company GlobeScan Inc., specialized in CSR matters regarding the stance of Greek consumers towards CSR promoting companies, it was identified that over 32,9% of Greek consumers has rewarded a socially responsible company (whether by purchase of a product or through positive comments expressed on this company) while 19,3% have thought in doing so. As such, a total of 52,2% of interviewees has rewarded or thought of rewarding a socially responsible company. Moreover, 48,4% of Greek consumers replied to have "punished" a socially irresponsible company (either through non purchasing of a product or through negative comments expressed regarding this company) while 17,8% have thought in doing so. In total, 66,2% overall - has punished and have thought of punishing a socially irresponsible company (GlobeScan Inc; Hellenic Network for Corporate Social Responsibility, 2009). Finally 80,9% of Greek consumers asked during this research believe that the social responsibility of a company should focus on ensuring that its products and operations are produced and conducted in an

environmentally friendly manner while 21,1% believed that large corporations should actively be involved through CSR actions in the improvement of the environment in local communities.

Table 28: Results of 2009 CSR related study in Greece (GlobeScan Inc; Hellenic Network for CorporateSocial Responsibility, 2009)



According to the data of the particular CSR 2009 research, the solemn act of "punishment" of a socially irresponsible company puts Greece in second place in the ranking of European countries. This fact coupled with the above statistics related to the rewarding of companies indicates that exhibiting a developed CSR role is highly esteemed and rewarded by the Hellenic society. This is an important fact regarding the use of small wind turbines in according applications since it implies the potential success of such investments both in terms of achieving conventional energy consumption reduction but also receiving consumer approval benefits from exhibiting a developed CSR role. Nonetheless despite the above it was determined, by the interviews of small wind turbine related Hellenic companies conducted for this thesis, that such applications have still not been considered or implemented in the country whatsoever.

Hellenic companies in the field of small wind turbines, for which interview results are presented in Table 11, have provided information from which important conclusions can be drawn regarding the current potential of applications focused on promoting the Corporate Social Responsibility (CSR) role of company investors while reducing greenhouse gas emissions via renewable energy production. The results clearly present the striking fact that none of the interviewed companies has been oriented in CSR related operations throughout their lifetime in Greece since all twenty one (21) of interviewees responded negatively to the according question. Additionally a significant number of them was not familiar with the term or had not been aware of such applications or the manners in which profits could be gained from them for either investors or installing companies. Furthermore a reluctance to proceed to the realization of such implementations in the near future was identified, even if the according legislation was clear and SWT promoting. In particular Figure 60 presents the results of the interviews.



Figure 60: Interview results conserning the viability of CSR promoting oriented projects in Greece

As identified 43% of responders did not believe that a CSR-small wind turbine market could be established or grow significantly in Greece. As a matter of fact, certain company spokesmen expressed their concerns regarding the matter claiming that such applications would be misleading to the general public since they would shift the end goal of the particular technology usage from eco-friendly viable energy production to corporate marketing (Green) "Image-making" and would strengthen the anti-wind energy opposition groups in the country which currently characterize the overall technology as inefficient and unsubstantial to the contribution of RES energy in substituting fossil fuel. Also concerns regarding installation aspects as well as uncertainties regarding technical issues (NIMBY concerns originating from noise perception being the most frequent) as well as market mismanagement among an economic crisis environment which could lead to an equivalent to the photovoltaic market "bubble", were mentioned.

Despite the above the majority of Hellenic SWT companies did not share the above opinions and were positive regarding the use of turbines on corporate buildings. Either to be installed on company rooftops and be directly visible by consumers or implemented in industrial buildings near urban centers in order for industries to exhibit indirectly their Social Responsibility regarding the protection of the environment and reduction of emissions efforts in the manner stated by the EU proposed Directive previously described, such concepts were considered viable under certain conditions. These conditions concerning Hellenic RES market associated economic and legislative barriers (presented in Chapter 4), if were to be met in the near future then CSR oriented small wind turbine installations could have a future in Greece. The results of the turbine supplying company interviews coupled with the data regarding Greek consumers, the ongoing efforts of the EU in promoting CSR actions and the allowing by the Hellenic legislation of Net Metering operating SWT systems, indicate that the promotion of this technology through the establishment of such a market in Greece, exploiting the adoption of small wind turbines for CSR promotion purposes, could be considered as both a near and medium term action to be supported and encouraged especially by nongovernmental company stakeholders. Moreover the creation of such a market will broaden the target group and as re-orient the focus of Hellenic SWT supplying companies regarding potential implementations allowing thus for the bypass of current household consumer related bottlenecks. As such the measure can be considered to be working on a macro level.

More analytically with the issuing of Net Metering (including the terms previously described and proposed) company investors will be able to implement turbines by avoiding time consuming and costly licensing procedures and will be independent of Government regulated support mechanisms which in the past have put the market on hold. Companies which will choose to implement such systems may also include other RET as well and thus make use of hybrid RES stations which will overall increase energy production and will enable for more versatility in terms of energy use management. In order to promote such applications though, attractive CSR specific product and turn-key projects offers must be issued by the turbine Suppliers. It should be noted that since the technology will remain immature during the near term future, implementations should be initially focused on near-urban located buildings or company owned areas and CSR benefits be gained through the issuance of according published information. For this reason and since as it has been presented in the previous techno-economic analysis larger turbines are currently more cost effective than smaller ones, 20kw to 50kw machines should be predominantly implemented. Regarding the medium term actions, with the gradual development of the technology and the successful addressing of technical limiting factors, companies may proceed to the installation of more systems in the urban fabric and aim at covering an increased amount of their energy requirements by them. Also smaller turbines could be used which will be easily visually recognized by the general public thus achieving both the goal of advertising a developed CSR profile as well as raising awareness regarding the use of this RET.

5.6 Raising awareness and increasing social acceptance

As implied by the almost non-existent number of On-grid and the relatively small number of Off-grid installed systems, consumer awareness regarding this technology, its associated benefits and applications in Greece is low. As such actions regarding the familiarization of the public with SWT are considered of outmost importance for the successful creation of a niche market which will potentially mature and be established in the country and thus are considered as micro level actions. Furthermore, although it is not possible to contribute as much as large scale wind energy in terms of achieving the according European renewable power capacity targets of 2020, small wind turbines apart from effectively covering the energy needs of potential investors in the field, due to their proximity to households and visual identification, can play a more than important role in spreading awareness and aiding or even accelerating the acceptance and use of wind energy in general. Thus, informing the public can have additional beneficiary effects to RES penetration.

As identified by the research conducted for this thesis, the theoretical background regarding the potential benefit of this technology exists and can be identified in international research. Also in a country level, Greece possesses the according authorities as well as permanent institutional information centers in order to spread and diffuse knowledge but unfortunately the efforts conducted up till now by MEECC, CRES, Technical Chamber of Greece, Special Secretariat for Competitiveness and Innovation and predominantly HWEA (with the issuing of the currently only strictly SWT technology focused publications) have not sufficed or have covered only partially the different aspects of small wind turbine implementations. Essentially the public must become aware of the potential specific benefits of small wind turbines operating under the current legislative framework and especially in high wind potential mountainous and island regions in which such applications are expected to be highly cost effective.

As such, relative credible publications, consumer guides and technology related fact sheets as well as potential safety and hazard related fact sheets issued by both governmental and non-governmental actors and especially with the collaboration of supplying companies with entities under the supervision of the according Ministry, are characterized as a near term action necessary for the acceptance of this technology. Another near term action to be considered is the issuing of relative information campaigns presented through mediums such as cable television, newspapers, flyers and information sessions, aiming at a primary target group, which in the particular case should be the general public of the regions with high RES potential and therefore high investment interest. Also all related groups such as Engineers, Consultants, local administrative authorities and technical chambers must participate in the spread of information through different communication channels and manners.

Apart from raising awareness regarding the operational and economic aspects of SWT implementation, actions are required to overcome or even prevent local opposition related barriers. Since SWT technology can be deployed in close proximity to households it is important that these actions will focus in the direct involvement or even rewarding (only in the case of upper-limit 50kw turbines) of communities regarding the realization and support of such projects. Internationally such actions have been investigated and according solutions have been proposed for increasing community acceptance. More specifically as stated in the research of A.L.B Heagle et al. regarding small wind turbine energy policies in Canada, the direct participation of the public in the SWT project planning phase through the use of collaborative partnerships (Energy Efficiency and Renewable Energy (EERE), 2008) and the immediate providing of information regarding the details of potential projects can establish communication paths which will allow for the possibility of openly expressing concerns and ideas in community meetings and the establishment of a fair procedure perception. Eventually this participation in decision making will play a crucial role in increasing the social acceptance since even in the case of an outcome not favorable for the opposing party, acceptance is more likely to occur when the outcome has been perceived to originate from a fair process (fair process effect) (Heagle, Naterer, & Pope, 2011). Nonetheless a concrete legal framework which will accurately define all aspects of SWT deployment is more than necessary in order for both opponents and implementers to be aware of their rights and limitations when supporting their positions in order to avoid imposing their views.

Also as claimed in literature, local residents are likely to support or most commonly oppose to a novel SWT project based on their *assumptions* and not experience regarding the final aesthetic or noise intrusion result (Heagle, Naterer, & Pope, 2011) since the majority of them cannot form firsthand experience-based opinions due to the high possibility of the existence of very few installed turbines in their proximity. Thus it is likely that biased and incorrect opinions may be formed and even established having an end result the community opposition to new projects. As such, the prior to new installation on-site familiarization of the public with actual SWT is considered a necessity. This can be achieved through the aid of suppliers and installation companies which can organize events in the form of field trips or through governmental intervention regarding access to test facilities in order to present with actual, quantified data the case of operating turbines. It follows that since such facilities do not exist currently and based on the previous arguments regarding the issuing of R&D in the country, this action is considered to be of medium term

5.7 Overall recommendations

The above analysis has aimed in providing applicable measures which can work on different level approaches and that need to be adopted or promoted by Greece in a specific time frame in order for the realization of the SWT technology and according market establishment to occur. Propositions specific to the barriers faced by Greece and most importantly the identified predominant barrier which did not allow for the small wind turbine sector to grow, have thus been described. It is understood that these measures do not cover explicitly and in every detail the actions required to be undertaken by the Hellenic state or stakeholders since the number of related technical, social and economic parameters are currently unavailable for Greece and thus would render this task as very complex and beyond the scope of this thesis. Nonetheless the above described measures can be considered as a set of realistic guidelines, following the manner equivalent propositions have been presented in European and US programs conducted by research institutes, namely Wineur and NREL's Built Environment Wind Turbine Roadmap.

As such, Table 29 is presented below which provides a summarized version of the propositions described previously. An attempt has been made in categorizing these actions based on three distinct axes of analysis thus combining the methodologies of both the Wineur program and the NREL Roadmap. These axes include the Stakeholders (Wineur), the level in each action can work (Wineur) and time frame (NREL). To the best of the author's knowledge, this form of categorization of SWT promoting actions for the case of Greece is novel in relative literature.

	Near Term	Medium Term		
	Innitiation Of SWT installations operating under Net Meetering system including required considerations	Interconnection of the Islands with the Mainland System and creation of Smart Grids	Governmental Actions	
Macro Level	Issuing of SWT Government Funding Scemes and Investment Laws	Initiation Governmental Institution Research and Development programs		
	Self-funding Strategies with the cooperation of Energy Service Companies (ESCOs) or restructuring if internal financing schemes	Creation of institutionally owned capital fund pools or Green Revolving Funds (GRFs)	Building Owner,	
	Implementation of ESA and MESA external funding models	Initiation Private party Research and Development programs	Supplier/ Installer, Investment Fund Actions	
	Promotion of Corporate Social Respondie			
Micro Level	Adoption of existing foreign Standardization Code			
	Evaluation and Certification of currently existing in the market SWT which fullfil quality criteria	Creation of detailed development plan for the gradual and controlled installation of SWT	Governmental/	
	Allowing of SWT installation only by Certified trained personnel	Reduction of cost and time required for the FIT licensing procedure	Certified Bodies Actions	
	Issuing of Spatial deployment and Urban planning regulations	Adoption of IEC 61400-2 Standard or proceed to issuing Hellenic National Standard		
	Issuing of information campaigns to raise	Supplier,		
		Consultant, Private Company Actions		

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6 Conclusions and Reflections

The final Chapter of this Thesis will include the conclusive remarks regarding the implementation of Small Wind Turbines in Greece as well as reflections upon the work conducted by the author. A general overview of the work conducted during the completion of this project will be first given, highlighting specific areas of interest and the estimation for the future of this technolgy in the country will be argued. Following, the knowledge acquired and strong points as well as the limitations of this Thesis will be described in order to provide the reader with the opportunity to understand from the perspective of the author, the considerations taken into account in order for the realization of this work to take place. Finally suggestions for future research will be presented based on the findings and thematic axes of this Thesis.

6.1 Thesis Conclusions

During this thesis an effort to identify, analyze and address the current situation and barriers to the establishment of Small Wind Turbines in Greece has been performed. The investigation focused in adequately covering three main research questions, as stated in the Introduction, which essentially synopsize the aim and govern the content of the work presented.

As such, after the initial description of the SWT technology as well as techno economic related information which helped build the required knowledge for the reader to be able to sufficiently comprehend the barriers related to this technology, a specific relevant analysis was conducted for Greece in which the general economic environment, legal framework and Institutional/Organization Stakeholders was described. Furthermore the Hellenic wind resources were assessed and it was determined that the numerous islands of Greece as well as mountainous areas possess ideal average annual wind velocities rendering potential investments in the field as potentially very attractive. In lack of specific information regarding the number of units installed, location of installation, installed power and other parameters of the SWT implementation in the country by relevant authorities, an investigation via questionnaires and verbal communication with small wind turbine Suppliers/Importers was conducted through which important data were gathered that enabled the author to depict the current market status of this technology in Greece. This investigation was coupled with the direct application of economic models described initially for the technology of SWT in Greece and relevant parameters were calculated, while three realistic distinct economic scenarios with actual Hellenic Market inputs were simulated using the RETScreen 4 software and conclusions regarding their viability were drawn. With a comparison with the predominant competing technology of Photovoltaics upon the completion of Chapter 3, the first research question regarding the technological and economic potential for SWT implementation in Greece was covered.

Continuing, the relative barriers for the growth of this market in the country were determined by following the framework analysis proposed by J.P.Painuly. The different barrier categories were analyzed in their corresponding elements and adapted for analyzing the Greek specific obstacles that disrupted and still hinder the deployment of these machines. With the completion of Chapter 4, the second research question concerning the factors which are limiting SWT development in Greece was effectively answered.

The conclusions drawn from the barrier identification were used in order to propose specific measures, after consulting relative literature originating from equivalent European and US programs since Hellenic relevant studies have not been conducted or were unable to be identified. Actions categorized based on time, level of approach and according stakeholder were presented in order to provide with concrete measures which could essentially "jump-start" this stagnant market sector and exploit the potential of the country. Specific notice was given in overcoming the predominant and most identified by Hellenic SWT Suppliers barrier for which the presented measures and especially the issuing of the Net Metering System formed the "backbone" of the proposed actions plan. Upon the completion of Chapter 5, the last research question concerning measures (policy) which can help overcome the SWT deployment barriers in Greece was answered by providing feasible solutions.

By the analysis conducted by this Thesis, the overall derived conclusion that political will is the main governing factor regarding the implementation of these machines was drawn. The research has revealed that in the past even though the legal foundations for the widespread use of SWT existed, the wind potential of the country is favorable and companies with experience in the field (mainly by the installation of Off grid systems) were present, the "take off" of this particular market never took place due to the inability of the government to effectively manage the overall energy sector financing system, which derailed after the irrational and unplanned introduction of photovoltaics, and its inability to impose the following of according regulations by all stakeholders.

Today, due to a number of factors such as the fact that the Hellenic wind energy targets of 2020 have not been covered in contrast to the according Photovoltaic ones, SWT are currently the direct market competitors of the latter, the LAGIE funding mechanism is progressing towards rationalizing it's deficit, the islands will be interconnected to the mainland system allowing for energy transactions and the Net Metering System has already been legally adopted by the country, the space for this new niche technology within the incumbent energy system is indicated to be available. The success or repeated failure to the establishment of a SWT market lies in the willingness of the according Ministry and other party stakeholders to embrace this technology which can potentially contribute to the economic growth of the country and continue to the necessary market reforms. Nonetheless, even with the issuing of Net Metering which will render this particular sector much more dynamic than in the past where it was bound by multiparty lengthy procedures and financial control, still support is to be required. If this support is actively provided by the issuing of the presented measures of this thesis but also by measures proposed by future in depth techno economic studies, the Hellenic Small wind turbine market may even face a brighter future in Greece than its Photovoltaic counterpart which faced the consequences of quick and short term profit deployment.

It is imperative to stress that Greece is still in economic crisis and experiencing austerity and as such any speculations about the future, especially of a niche market offering a non-fully mature product, may be problematic. Also the general RES market in the country is at its worst financial state since 2005, a fact that could possibly prioritize existing technologies of large scale which could quickly cover EU obligations over new small scale ones thus hindering any development in the field of widespread SWT introduction. Nonetheless, it is the author's opinion that small wind turbines will have a future in the country but their overall success will be strongly affected by the rate of realization of Hellenic specific barriers, the rate of progress regarding the above stated policy reforms and finally the timespan during which Greece will finally exit the economic crisis environment.

6.2 Thesis Reflections

This Thesis gave the author the opportunity to explore and investigate Small wind turbines aspects of implementation from a different perspective than that of the strictly computational or experimental Engineering discipline and allowed for the realization of two important considerations : the significance of policy making in the manner it affects the successful or unsuccessful adoption of a technology (especially in his country of origin) and the fact that an Engineer must always reflect upon the reasons (social and economic alike) for which a specific product or project should be created or followed through respectively.

The fact that the Thesis was focused in identifying the Greek specific barriers made it possible to gain valuable knowledge about the current reality faced in the country regarding SWT but also RES in general and allowed for the determination of the Hellenic energy and government sector's inherent inefficiencies which did not allow for the up till now implementation of the technology.

Due to the fact that no official data regarding the already installed SWT in Greece existed, the author was urged to conduct a novel relevant research which brought him in contact with the president of HWEA Dr. Ioannis Tsipouridis, CRES's SWT responsible authority Dr. Kyriakos Rossis, HEDNO and IPTO officials and more than thirty companies in the field of small wind turbines who shared more than valuable information currently not to be found elsewhere. This proves to be a strong point of this Thesis.

The economic evaluation of SWT projects familiarized the author with investment related terms and parameters and provided the opportunity for their actual application, thus signifying another strong point of the current work. Through economic model calculations and the RETScreen 4 simulation software realistic scenarios were evaluated revealing significant information and providing insight on according investments. Via this analysis the importance of the complete assessment, understanding and quantification of SWT potential benefits was underlined.

Furthermore, the determination of barriers in Greece has covered gaps in the existing literature by adding to the current knowledge through the building and extending of research and implementation and adaptation of existing analysis frameworks (J.P.Painuly). To the best of the author's knowledge, such detailed and categorized analysis of the current Hellenic related barriers of this technology is not present in literature or concentrated in a single document.

The building of knowledge regarding the existing barriers faced by SWT in Greece has allowed the author to adopt a critical stance in order to propose applicable solutions which do not rely only on general widely acknowledged guidelines but also provide specific and targeted measures which would be possible to be practically adopted. Following the principle that novel and groundbreaking actions are required, the focusing of the industry to CSR applications was thus argued among other measures' a proposition that the author has not yet come across either in his research for this thesis or in his years as an Engineering Student and Engineer in Greece.

Regarding the limitations faced during the completion of this Thesis, the fact that actual data regarding the existing number of SWT installed On and Off grid did not allow for an accurate quantification of the status of this market based on official data. Furthermore the investigation, which was conducted due to the above limitation, depicted personal opinions, statements and information which were impossible to cross check regarding their validity and in total were not bias-free regarding the role of the Government and the reasons for the current status of the technology.

Another limitation of the Thesis regarding the calculations and simulations performed were the use of inputs solely regarding 50kw turbines. Since the price levels as well as energy production does not scale linearly with the different power output of machines, the results may not be highly representative for smaller size and power output machines and as such should best be used to provide indicative results concerning the entire range of the technology.

The fact that no prior research has been conducted regarding the social opposition in Greece regarding SWT did not allow for actual argumentation on the subject which would accurately reflect the case of the Hellenic society. Information regarding social opposition and noise perception originated from UK studies depicting the idiosyncrasy of the British people participating in the studies.

In retrospect, this Thesis could have also used a different framework of barrier analysis than that of J.P.Painuly. The limitations of this framework, mainly existing due to overlaps of barrier elements in different categories, unclear categorization and division of barriers creating sometimes confusing similarities, often led the author to deviate from it. From one side this fact can be considered creative but on the other the strength of an analysis framework lies on its applicability to reality.

Based on the existing work, future research could further focus in SWT aspects based on three distinct axes of investigation:

- 1. Investigating in depth the social aspects of SWT deployment in Greece and more specifically quantifying the awareness and acceptance of the Hellenic population regarding such applications. Significant surveys are required especially regarding household consumers in high wind potential areas and specifically the islands in order to understand or even prevent proximity related issues which have been described in this thesis.
- 2. Investigating SWT deployment based on a different frameworks of analysis to explore different approaches and paths which could reveal other aspects, facts and important information regarding this technology in the particular country (for example the ties between different companies and how knowledge is diffused through them)
- 3. Researching in depth the potential benefits of SWT implementation in CSR promoting application and more specifically quantifying the potential benefit individual companies would have from installing SWT on their facilities. Apart from general public surveys to establish on whether consumers would be willing to pay slightly more for specific product or prefer one company from another if they knew SWT had been installed on corporate facilities, studies should be conducted to calculate the actual benefit for a given period of time (for example a specific quarter of the year).

7 Appendix



Figure 61: Increasing trend of installed power from Wind Energy (Global Wind Energy Council , $$2012\)$



Figure 62: Installed power for Offshore Wind Energy per country (Global Wind Energy Council , 2012)



Figure 63: SWT mouted on wall perpendicular to the roof area (Power Turbine, 2013)



Figure 64: Interconnected Grid of Mainland Greece (Invest in Greece Agency, 2008)



Figure 65: Relation between the cycle life and the depth of discharge of a battery (Woodbank Communications Ltd, 2005)



Figure 66: Greek manufactured Butterfly SWT (Energotech, 2013)

Annex 1. Overview of Member States progress						
Member State	2005	2010	1 st interim	2020		
	RES	RES	target	RES target		
	share	share				
Austria	23.3%	30.1%	25.4%	34%		
Belgium	2.2%	5.4%	4.4%	13%		
Bulgaria	9.4%	13.8%	10.7%	16%		
Cyprus	2.9%	5.7%	4.9%	13%		
Czech Republic	6.1%	9.4%	7.5%	13%		
Germany	5.8%	11.0%	8.2%	18%		
Denmark	17%	22.2%	19.6%	30%		
Estonia	18%	24.3%	19.4%	25%		
Greece	6.9%	9.7%	9.1%	18%		
Spain	8.7%	13.8%	10.9%	20%		
Finland	28.5%	33%	30.4%	38%		
France	10.3%	13.5%	12.8%	23%		
Hungary	4.3%	8.8%	6.0%	13%		
Ireland	3.1%	5.8%	5.7%	16%		
Italy	5.2%	10.4%	7.6%	17%		
Lithuania	15%	19.7%	16.6%	23%		
Luxembourg	0.9%	3%	2.9%	11%		
Latvia	32.6%	32.6%	34.0%	40%		
Malta	0%	0.4%	2.0%	10%		
Netherlands	2.4%	3.8%	4.7%	14%		
Poland	7.2%	9.5%	8.8%	15%		
Portugal	20.5%	24.6%	22.6%	31%		
Romania	17.8%	23.6%	19.0%	24%		
Sweden	39.8%	49.1%	41.6%	49%		
Slovenia	16.0%	19.9%	17.8%	25%		
Slovakia	6.7%	9.8%	8.2%	14%		
UK	1.3%	3.3%	4.0%	15%		
EU	8.5%	12.7%	10.7%	20%		

Annex I. Overview of Member States' progress

>2% above interim target <1% from or <2% above interim target >1% below interim target

Figure 67: Interim and 2020 RES penetration targets and progress of EU member countris (European Commission, 2013)

		Climate							
		data	Project						
	Unit	location	location	T					
Latitude	Ň	36,7	36,7						
Longitude	°E	24,5	24,5						
Elevation	m	183	183						
Heating design temperature	°C	5,1							
Cooling design temperature	°C	31,7							
Earth temperature amplitude	°C	7,2							
				Daily					
				solar					
		Δir		-	Atmosph		Farth	Heating	Cooling
		temperat	Relative	horizont	eric	Wind	temperat	dearee-	dearee-
Month		ure	humidity	al	pressure	speed	ure	days	days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		10,7	71,9%	2,30	101,4	8,3	13,8	226	22
February		10,5	70,4%	3,17	101,3	8,6	13,5	210	14
March		11,8	67,8%	4,62	101,2	7,5	14,2	192	56
April		15,0	64,9%	6,19	101,0	5,9	15,9	90	150
Мау		19,2	59,5%	7,36	101,0	5,2	18,6	0	285
June		24,0	51,5%	8,36	100,9	5,2	21,7	0	420
July		26,0	52,5%	8,31	100,7	6,5	23,4	0	496
August		25,7	59,0%	7,50	100,7	6,6	24,0	0	487
September		23,2	63,7%	6,05	101,0	5,5	22,8	0	396
October		19,4	69,2%	4,21	101,3	6,5	20,5	0	291
November		14,9	73,7%	2,58	101,3	6,9	17,5	93	147
December		11,9	75,2%	1,96	101,4	8,3	15,1	189	59
Annual		17,7	64,9%	5,23	101,1	6,7	18,4	1.001	2.823
Measured at	m	1				10.0	0.0		

Figure 68: RETS creen 4 input data for the island of Milos located in the highly to uristic island group of Cyclades $% \mathcal{C}$

Wind speed	Power curve data	Energy curve data
m/s	kW	MWh
0	0,0	
1	0,0	
2	0,0	
3	2,5	22,0
4	3,2	47,1
5	4,7	83,2
6	10,1	125,7
7	15,0	167,7
8	20,9	203,1
9	28,6	228,8
10	37,4	244,3
11	50,0	251,0
12	55,0	250,8
13	55,0	245,7
14	55,0	237,4
15	55,0	227,1
16	55,0	
17	55,0	
18	55,0	
19	0,0	
20	0,0	
21	0,0	
22	0,0	
23	0,0	
24	0,0	
25 - 30	0,0	

Figure 69:Power curve data for SWT used in RETScreen 4 simulations



Figure 70:Turbines sited close by BIRD DEATHTRAP social barrier (cnet, 2008)



Figure 71: Prediction of LAGIE's deficit since December 2014 (B2Green, 2013)

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