Onshore wind farm siting prioritization based on investment profitability for Greece

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Abstract

A feasibility study is presented on mid-size onshore wind farms in Greece, taking into consideration two metrics for the evaluation of the profitability of the pertinent investment, namely the net present value, and the internal rate of return. An operationally complete wind park of ten 3.2MW turbines is considered, incorporating all required power conversion/transmission, and transportation infrastructure that an owner would have to construct. Actual wind speed data are employed from 285 weather stations installed throughout the country and covering a period of 1 to 12 years. The costs of installation, operation, and financing are explicitly accounted for over a standard lifecycle of twenty years. Given the regulated wholesale price for renewable electrical power, the proximity of many sites to ports, and the relatively uniform cost of investing, it is the wind potential that remains the governing factor affecting the financial viability of the wind park. Accordingly, the most profitable areas are the Aegean islands, the south-central mainland coastline, east Peloponnese, and south Attica. Most other regions of mainland Greece are found to be either marginally profitable or to generate a net loss given the current wholesale prices, wind turbine technology and investment costs.

Keywords:

Wind Energy; Wind potential; Onshore wind farm; Feasibility study; Investment valuation

1. Introduction

Recent years have seen a growing interest in Renewable Energy Sources (RES) and especially in wind energy. At the end of 2017 the installed wind power capacity in the European Union was 168.993 MW, while in Greece it was 2.541 MW [1]. Greece is a country with an extended coastline and a large number of islands. Strong winds, mainly blowing on the islands and along the coasts contribute to the development of the country's promising wind potential. Many actions have been taken to develop wind power throughout the country, taking also advantage of the subsidies of RES investments offered by the European Union.

The wind potential of a specific area is a crucial factor, as it influences the cost effectiveness of the investment and helps estimate future revenue. The wind potential of several Greek areas was examined in the literature, including the Aegean Sea [2], the Ionian islands and the western coasts of Greece [3], Crete [4], Western Greece [5], and the Dodecanese islands [6]. In general,

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relatively strong annual wind speeds were observed, hinting at the financial viability of onshore installations. More specifically, Kaldellis [7] examined Kythnos, a small Greek island in the southwest of the Aegean Sea, by using wind speed data for four years, concluding that a stand-alone wind power system can cover the energy requirements of the island. The analysis of the wind data showed that Kythnos is characterized by strong winds, which reach an annual mean value of 7 m/s at 10 m height in several locations. Viogatzis et al. [8] investigated the area of Thessaloniki in northern Greece, using wind speed data for the period 2000-2001, to show substantial energy potential, yet not enough for covering the city's needs. Fyrippis et al. [9] analyzed Naxos, an island in South Aegean, using wind data over the period 2006-2007, concluding that the annual mean of the wind speed recorded was 7.4 m/s. Palaiologou et al. [10] investigated the wind characteristics of Lesvos, a Greek island in North East Aegean Sea, by using wind speed data over the period 2003-2006 showing that the highest and lowest 10-min average wind speed values are 4.7 m/s and 2.7 m/s, respectively.

There are also several studies that take into consideration not only the amount of produced wind energy, but also other economic aspects that are important in determining the optimal siting of a wind farm [11-13], with at least one considering an island of Greece [14]. Typically employed metrics of investment profitability are the pay-back period (PBP), the net present value (NPV) and the internal rate of return (IRR). For example, Hamouda [12] conducted a financial analysis for Cairo, Egypt, using wind speed data from 2009 by applying the NPV and the IRR. The results showed that it is profitable to invest in Cairo, despite the low wind capacity of the area. Ismail et al. [13] performed a feasibility study of a wind farm for a coastal area in South Purworejo, Indonesia. They examined different scenarios and followed the methodology of NPV and IRR in order to find the most profitable installation site. Xydis [14] performed an economic feasibility study, using wind speed data from October 2007 to October 2008 for the Greek island of Kythera. Different scenarios were examined for optimizing wind farm planning, and the NPV values were estimated to identify the most profitable site.

Overall, such studies have used advanced financial assessment tools for a comprehensive view of investment feasibility, yet they have only applied them in small regions and using limited duration wind data. Herein, we aim to offer an extensive investigation for the entirety of Greece using the most comprehensive set of publicly available wind data to offer siting prioritization and investment decision tools for wind farm development in the near future.

2. Methodology

2.1 Collection and evaluation of wind data

A comprehensive set of wind data for the area in question, in terms of both number of weather stations and duration of recorded data, is necessary for a reliable application of the proposed methodology. For the case study presented here, wind speed data were downloaded from the interactive MeteoSearch database [15] administered by the National Observatory of Athens - NOA [16]. NOA has installed a dense network of weather stations in various places in Greece since 2006. In those stations several meteorological variables are recorded, such as temperature, wind speed, rainfall height, etc. For each station the average daily wind speed at the height of the station's anemometer is reported in the website cited above, and has been used in the calculations presented in this study. For reasons of completeness, the number of months of available wind speed data for the 285 stations are listed in Table A.1 of the Appendix.

It should be noted that wind speed values change over the height due to the variation in the frictional effect of the ground surface [17]. In the case of a wind turbine the wind speed at the hub height should be calculated. Assuming a power-law wind profile, the wind speed at the hub height is calculated according to the equation:

$$\frac{v_{hub}}{v_{ref}} = \left(\frac{z_{hub}}{z_{ref}}\right)^{a} \tag{1}$$

v_{hub} is the wind speed at the hub height in m/s, v_{ref} is the reference wind speed (in m/s) at the reference height z_{ref} (which is the anemometer's height of each station in m), z_{hub} is the hub height (in m), and a is the dimensionless power law exponent. Typical values for a are 0.14 for offshore areas and 0.20 for onshore ones [18, 19]. Herein, $a = 0.20$ was used, since onshore wind parks are considered and most of the weather stations whose data were used are installed in urban areas. For the considered GE 3.2-130 model the hub height is equal to 85 m, thus $z_{hub} = 85\ m$ has been adopted.

One of the most widely used statistical distributions for representing wind speed is the two-parameter Weibull distribution, which is recognized as an appropriate model and is widely used in the wind industry sector [10, 14, 20-22]. The probability density function (PDF) is expressed through the equation:

$$f(v) = \frac{k}{c} \cdot \left(\frac{v}{c}\right)^{k-1} \ e^{-\left(\frac{v}{c}\right)^{k}} \tag{2}$$

while the cumulative distribution function (CDF) is:

$$F(v) = 1 - e^{-\left(\frac{v}{c}\right)^{k}} \tag{3}$$

v (m/s) is the wind speed, c (m/s) is the scale parameter and k (dimensionless) is the shape parameter that shows how peaked the wind distribution is. The parameters c and k of the distribution are usually determined by employing the maximum likelihood method [23].

In the case of a wind turbine two more restrictions should be taken into consideration, namely that the turbine cannot produce any power below a cut-in wind speed v_{in}, while its control system prevents operation at wind speeds above the cut-out speed v_{out}, e.g., by feathering the rotor blades. Thus, the PDF of the Weibull function can be made to better fit the wind speed data within the operational range by explicitly accounting for the probability of v being less than v_{in} and greater than v_{out}. Hence, a four-parameter PDF can be used:

$$f(v) = \begin{cases} \mathrm{P}(v < v_{in}), & v = v_{in} \\ \dfrac{[1 - \mathrm{P}(v < v_{in}) - \mathrm{P}(v > v_{out})]}{1 - e^{-\left(\frac{v_{out} - v_{in}}{c}\right)^k}} \cdot \dfrac{k}{c} \cdot \left(\dfrac{v - v_{in}}{c}\right)^{k-1} e^{-\left(\frac{v - v_{in}}{c}\right)^k}, & v_{in} < v < v_{out} \\ \mathrm{P}(v > v_{out}), & v = v_{out} \end{cases} \quad (4)$$

The corresponding four-parameter CDF is:

$$F(v) = \begin{cases} 0, & v < v_{in} \\ \mathrm{P}(v < v_{in}) + \dfrac{[1 - \mathrm{P}(v < v_{in}) - \mathrm{P}(v > v_{out})]}{1 - e^{-\left(\frac{v_{out} - v_{in}}{c}\right)^k}} \cdot \left[1 - e^{-\left(\frac{v - v_{in}}{c}\right)^k}\right], & v_{in} \leq v \leq v_{out} \\ 1 & v > v_{out} \end{cases} \quad (5)$$

The dimensionless shape parameter k is similar to the case of two-parameter Weibull distribution but estimated only for $v_{in} \leq v \leq v_{out}$, $\mathrm{P}(v < v_{in})$ is the probability of the wind speed being less than the cut-in speed and $\mathrm{P}(v > v_{out})$ is the probability of the wind speed being greater than the cut-out speed. Thus, the probability P_{oper} of the wind speed to be in the operational range of the wind turbine is:

$$P_{oper} = 1 - \mathrm{P}(v < v_{in}) - \mathrm{P}(v > v_{out}) \quad (6)$$

The empirical (i.e. observed) distribution of the data could also be used for estimating the wind speed distribution for a specific site. This is a perfect description of the measured data and obviously requires no fitting, yet at the same time it is considerably more cumbersome to document vis-à-vis the four parameters of Eq. (4) or Eq. (5) and it may not adequately capture the long tail of the actual wind speed distribution when few observations are available. In our case, there was enough data at all stations to employ the empirical distribution, giving practically identical results to a 4-parameter Weibull fit. Yet, for obvious reasons of simplicity, only the Weibull parameters are presented in Table A.2 of the Appendix.

2.2 Description of the wind turbine

The type and number of wind turbines to be used in the wind park are necessary for calculating the initial investment and for estimating the expected energy production, making use of the turbine's so-called power curve. For this case study it was assumed that the park consists of 10 wind turbines and their type is General Electric's GE 3.2-130. The power curve of this turbine is depicted in Fig. 1, providing the generated power $P_{re}(v)$ for a specific wind speed v in the operational range. The wind turbine starts its operation at a wind speed of 3 m/s (cut-in speed, v_{in}) and stops at a wind speed of 25 m/s (cut-out speed, v_{out}). The diameter of the rotor is 130 m and the hub height is 85 m.

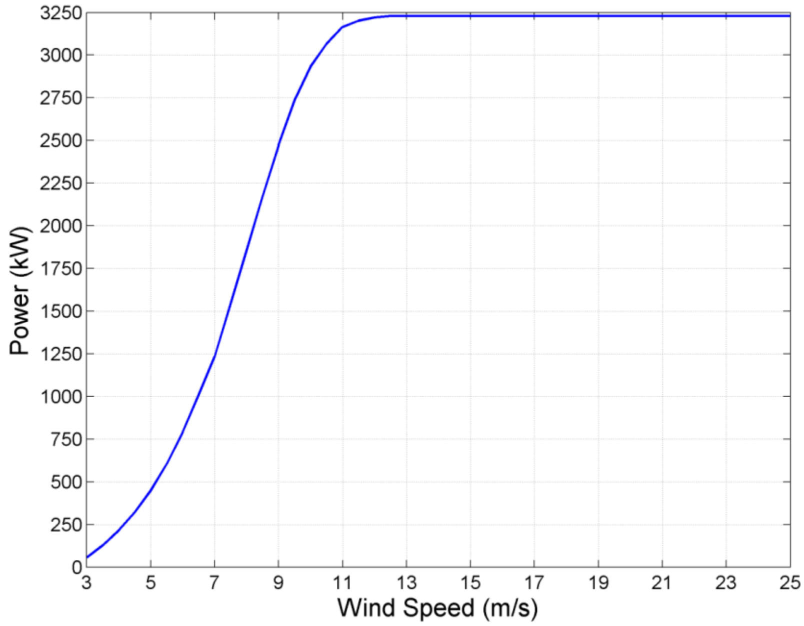


Fig. 1: Power curve of GE 3.2-130 wind turbine (adapted from [24])

2.3 Wind energy production and revenues

For the estimation of the energy production, the wind speed distribution and the power curve of the wind turbine are used. The probability of observing a specific value of wind speed $P(v)$ is estimated from the wind speed distribution. Considering that a typical year has 365.25 days and thus 8766 hours, the number of hours that corresponds to a specific value of wind speed over the period of one year is calculated by multiplying the probability $P(v)$ by 8766 hours. Thus, the produced energy $E_e(v)$ (in kWh or MWh) that corresponds to a specific wind speed v over the period of one year is:

$$E_e(v) = P_{re}(v) \cdot P(v) \cdot 8766 \tag{7}$$

where $P_{re}(v)$ is the turbine power (in kW or MW) for wind speed. Eventually, the total produced energy TE_e in one year is calculated by integrating $E_e(v)$ over all wind speeds, or simply over the operational wind speed range:

$$TE_e = \int_{v_{in}}^{v_{out}} E_e(v)dv \tag{8}$$

If a wind turbine is out of order for maintenance or due to a network fault, it does not generate power, no matter how powerful the wind is at that moment. According to wind turbine manufacturers the availability rate AR of a turbine typically ranges from 95% to 98%. In addition, network losses NL and shading losses SL that affect the average annual power should be taken into account. Considering the above the final annual net energy production AEP_{net} of a wind farm with N wind turbines is:

$$AEP_{\mathrm{net}} = TE_e \cdot N \cdot AR \cdot (1 - NL - SL) \tag{9}$$

The availability rate was considered to be AR=98%, the network losses NL=3% and the shading losses SL=3%. Finally, the revenue Rev of a wind farm (e.g. in EUR) comes from the sale of electricity and is estimated as:

$$Rev = AEP_{\mathrm{net}} * R_{FiT} \tag{10}$$

where R_{FiT} is the price per MWh (e.g. in EUR/MWh) as determined by the Feed-in-Tariff (FiT) in Greece. Essentially this enforces a constant wholesale price that is provided by the Regulatory Authority for Energy (RAE). Currently, R_{FiT} is 87.85 EUR/MWh for the network-connected areas (mainland and a few nearby islands) and 99.45 EUR/MWh for the unconnected areas (most islands).

2.4 Investment valuation metrics

The initial investment cost IC for the construction of an onshore wind farm includes the costs of civil engineering works, electromechanical equipment, design and feasibility study and other miscellanea.

In addition, the operation cost $Oper$ of the wind farm should be taken into consideration. It consists of the insurance and service cost ISC, the maintenance cost MC, the municipal fees MT and the other costs OC:

$$Oper = ISC + MC + MT + OC \tag{11}$$

The Net Present Value [25, 26] is one of the metrics that can be applied to evaluate an investment decision. Net Present Value (NPV) is defined as the difference between the present value of cash flows and the present value of cash outflows over a time period. A positive NPV shows that the present value of cash inflows exceeds the present value of cash outflows and hence the investment should be made. However, a negative NPV indicates that the investment should be discarded. In general, zero NPV means that the proceeds from the project repay the initial investment, without any benefit or damage to the investor. Therefore, a positive NPV means that the investment is profitable, while a negative NPV means that the investment results in a loss. Mathematically:

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} - IC \tag{12}$$

CF_i is the net cash flow over the time period i, r is the discount rate and n is the useful life of the investment, herein, taken as 20 years. All cash flows are discounted except for the initial investment IC, which is anticipated to take place in the present.

Apart from the NPV, the internal rate of return (IRR) is another widely used metric for the evaluation of investment decisions [27, 28]. IRR is the discount rate r for which the NPV becomes zero in Eq. (12). If the IRR is lower than the discount rate, then the investment is discarded, and if the IRR is higher than the discount rate then the investment is accepted. In general, the investment option with the highest IRR is preferred.

To estimate the cash flow CF_i for each time period i a number of steps is required. First, the gross profit, GP, is calculated as the difference between the revenue Rev and the operational expenditures $Oper$:

$$GP = Rev - Oper \tag{13}$$

Then the taxable income TI is estimated by deducting the depreciation $Depr$ and the interest payments Int from the gross profit:

$$TI = GP - Depr - Int \tag{14}$$

Thus, the net profit after taxes, $NP_{aftertax}$, is obtained as:

$$NP_{aftertax} = TI - Tax \tag{15}$$

where Tax are the taxes paid, calculated by multiplying the taxable income by the tax rate, TR:

$$Tax = TI \cdot TR \tag{16}$$

Herein, TR is considered equal to 25%.

Finally, the cash flow CF_i for period i is calculated by adding the depreciation $Depr$ to the net profit after taxes:

$$CF_i = NP_{aftertax} + Depr \tag{17}$$

The discount rate r represents the cost of capital or, in general, the interest rate that someone could have earned if the money was invested in the best alternative investment. When applying Eq. (12), r is estimated as the weighted average of capital cost $WACC$, which depends on public subsidy, private capital and private bank lending and it is calculated as:

$$\text{WACC} = \frac{E}{IC} CoE + \frac{D}{IC} CoD(1 - TR) \tag{18}$$

where E is the equity, D is the debt, CoE is the cost on equity and CoD is the cost on debt.

CoE and CoD in general differ among European Member States. In Greece, for onshore wind park projects, Tesniere et al. [29] has calculated CoE in 13–17.5%, CoD in 7–11%, and WACC in 10.5–13.7%. Angelopoulos [30] based on interviews, reported values of CoE in 13–17.5%, CoD in 7–11%, and WACC in 10–12% for the year 2016. Herein, CoE was considered equal to 13% and CoD equal to 7%, while the WACC was estimated according to Eq. (18) for each specific site studied.

The initial investment cost IC for the construction of a wind onshore farm should be funded. There are three main sources of funding: the equity, the subsidy and the loan. In Greece, Law 3908/2011 [31] poses some restrictions to the sources of funding. Regarding the equity, the percentage of the investor's own funds cannot be less than twenty-five percent (25%) of the initial investment cost. The percentage of subsidy depends on the zone an area belongs to and on the size of the company. For the determination of the subsidy, Greece’s territory (Fig. 2) is divided into three zones of incentives (A, B, C) based on the level of development compared to the average of the country. Incentive Zone A includes the prefectures of Attica and Viotia, Incentive Zone B includes the counties that have a GDP per capita greater than 75% of the country average; and Incentive Zone C, includes the counties with a GDP per capita less than 75% of the country average. Furthermore, the Region of Eastern Macedonia and Thrace, the islands of the South and North Aegean Sea, the Ionian Islands, the islands that are administratively owned in the prefectures of mainland Greece and the border counties of the country belong to Zone C. Table A.3 of the Appendix shows the prefectures that each zone includes as well as the rate of subsidy for each zone. Businesses are categorized as large, medium, small and very small. The rate of subsidy of each investment project depends on the size of the investment, the county in which it is implemented and in any case may not exceed 50% of the initial investment cost. As far as the loan is concerned, it should be at least for a 4-year period. Herein, the loan period was considered to be of 10 years based on similar studies in the Greek market [14].

3. Single Site Example

As an example of the methodology described in the previous section, a detailed feasibility study for the case of the Greek island of Lemnos is presented. The island of Lemnos is located in the north part of the Aegean Sea (Fig. 2) and administratively belongs to the Lesvos Prefecture. According to Table A.3 Lemnos is included in Incentive Zone C, while for government subsidy purposes the wind farm is considered a medium size business.

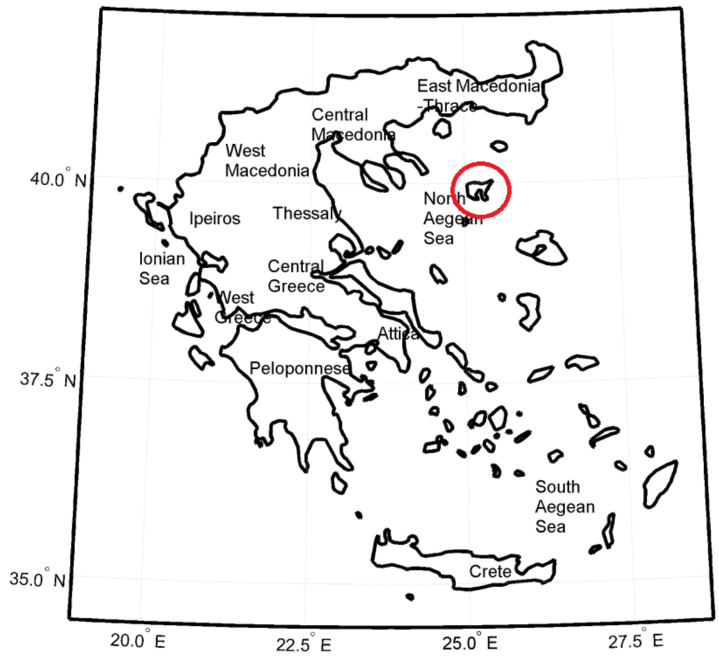


Fig. 2: Map of Greece and its prefectures, showing the island of Lemnos to be used as an example.

The closest weather station (LGI5, Table A.1) is located on the island at 39°55’N and 25°20’E and at an altitude of 22 m. The anemometer height above ground is equal to 5 m. The period of wind data available is equal to 106 months (approximately 9 years). The wind speed distribution for Lemnos is presented in Fig. 3, showing both the empirical PDF and the Weibull PDF for wind speeds lying in the operational range of the wind turbine. The average daily wind speed at the hub height was estimated as 5.15 m/s. The probability of the wind speed being lower than v_{in} is $\mathrm{P}(v < v_{in}) = 0.3327$. On the other hand, the probability of the wind speed being higher than v_{out} is $\mathrm{P}(v > v_{out}) = 0.0003$. Thus, according to Eq. (6) the probability of wind speeds in the operational range of the wind turbine is $P_{oper} = 0.6670$. As far as the scale and shape parameters c and k of the Weibull distribution are concerned, the maximum likelihood method gives $c = 3.98\, m/s$ and $k = 1.15$.

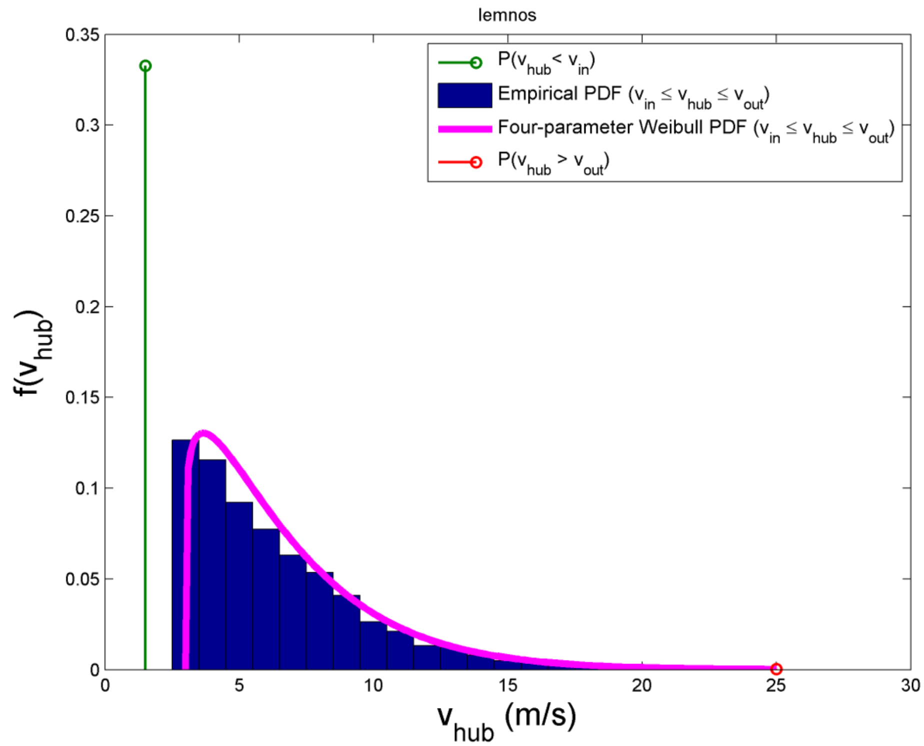
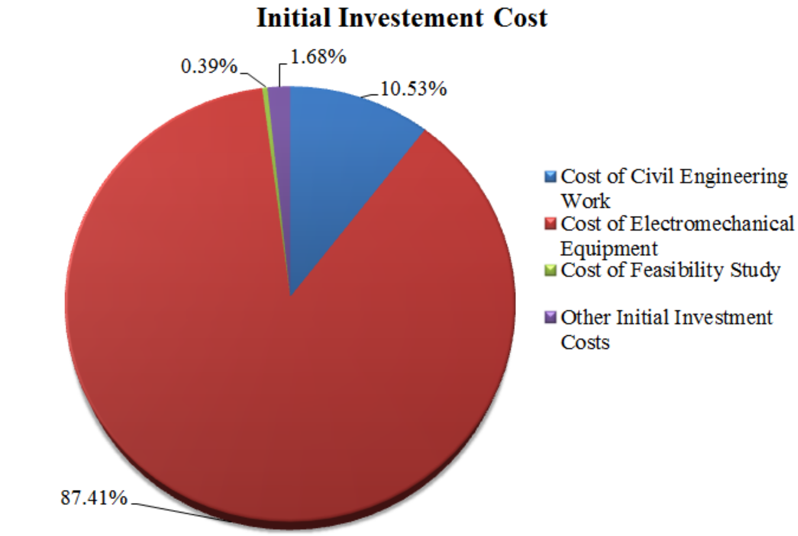


Fig. 3: Wind speed distribution at hub height for the island of Lemnos, showing the empirical and the fitted PDFs for operational wind speeds, as well as the two probability masses for wind speed lower than cut-in speed and higher than cut-out speed.

Following the methodology of section 2.3, the annual produced energy (considering the availability rate and the losses) for a wind farm that consists of 10 turbines was estimated to be equal to 67,917 MWh. The revenue of a wind farm comes solely from the sale of electricity. Lemnos is a non-interconnected area and therefore the price per MWh produced is 99.45 EUR. Thus from Eq. (10) the total annual revenue is equal to 6,619,214 EUR.

The financial inputs considered are presented in Table 1. They are the result of expert opinion elicitation from companies specializing in onshore wind farm investments in South Europe. Based on the reported data, the total initial investment cost for the construction of a wind farm consisting of 10 GE 3.2 MW wind turbines is 29,825,000 EUR, including the cost of equipment, the feasibility study, and the associated site preparation works. In specific (Fig. 4), the cost of Electromechanical Equipment has the greatest contribution constituting 87.41% of the initial investment cost, while the cost of Civil Engineering Work contributes to 10.53% of the cost. Finally, the corresponding percentages of the feasibility study and other costs are equal to 1.68% and 0.39%, respectively. The financial scheme is: 25% Equity, 35% bank lending (loan) and 40% public subsidy for the case of a medium-size business. The loan has a fixed interest rate of 7% and its duration is 10 years. The annual operating costs are 878,576 EUR and are considered to remain stable for the 20 years of operation of the wind farm. Maintenance Costs, as expected, constitute the main operating cost with a percentage of 56.91% (Fig. 4). Moreover, the Municipal

Taxes correspond to the 22.60% of the operating cost, while the Insurance and Service Costs to 17.07%. Finally the administrative and other costs have minor contribution (1.71% each).



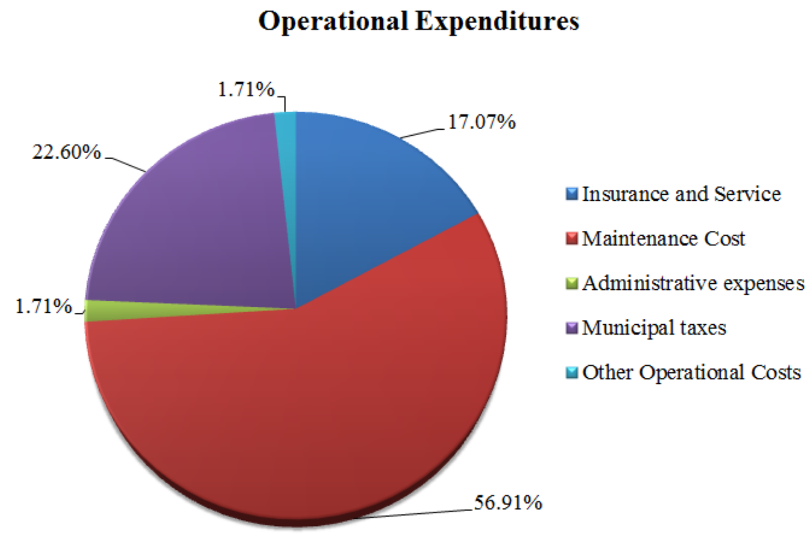


Fig. 4: Contribution of different types of costs to Initial Investment Cost (top) and to Operational Expenditures (bottom)

Table 2 shows the depreciation cost for each year. For civil engineering costs and feasibility costs, the depreciation factor is 12%, while for the cost of electromechanical equipment and the cost of transporting and installing the equipment, the depreciation factor is 10%.

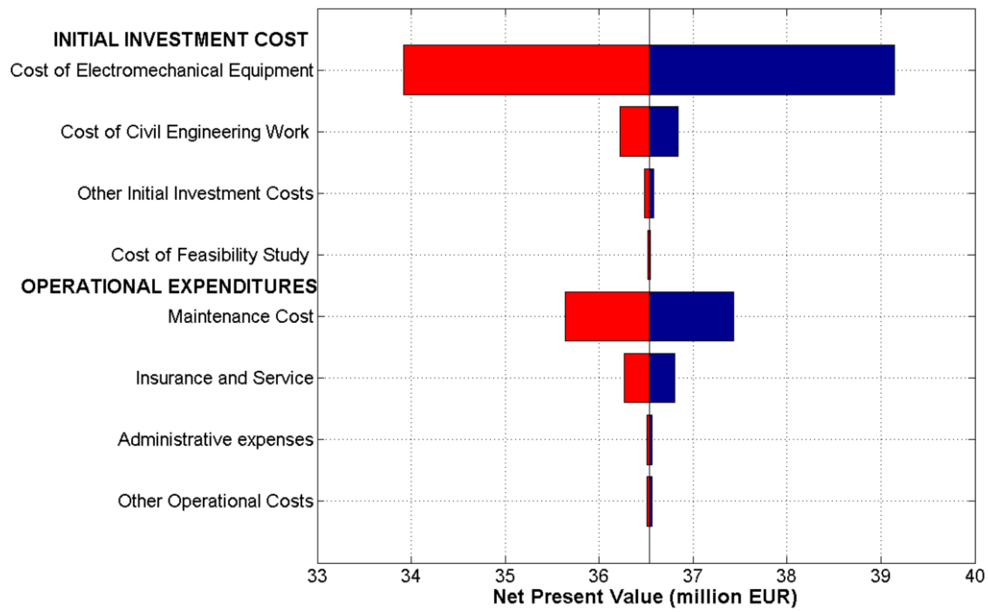
Table 1. Financial parameters for the Lemnos case study.

Parameter	Value	Parameter	Value
Initial Investment Cost (EUR)		**Operational Expenditures (EUR)**	
Cost of Civil Engineering Work	3,140,000	Insurance and Service	150,000
Cost of Electromechanical Equipment	26,070,000	Maintenance Cost	500,000
Cost of Feasibility Study	115,000	Administrative Expenses	15,000
Other Costs	500,000	Municipal Taxes	198,576
TOTAL	29,825,000	Other Costs	15,000
		TOTAL	878,576
Financial Scheme (EUR)		**Loan characteristics**	
Private Equity	7,456,250	Interest rate (%)	7
Private Bank Lending	10,438,750	Number of payments	120
Public Subsidy	11,930,000	Loan amount (EUR)	10,438,750
TOTAL	29,825,000	Annual payment (EUR)	1,486,243
		Duration (years)	10

Table 2 Depreciation costs for the Lemnos case study

Cost (EUR)	Year									
	1	2	3	4	5	6	7	8	9	10
CivilEngineering Works	376,800	376,800	376,800	376,800	376,800	376,800	376,800	376,800	125,600	0
Elect/Mech Equipment	2,607,000	2,607,000	2,607,000	2,607,000	2,607,000	2,607,000	2,607,000	2,607,000	2,607,000	2,607,000
Feasibility Study	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500
Assembly & Installation	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	20,000	0
TOTAL	3,055,300	3,055,300	3,055,300	3,055,300	3,055,300	3,055,300	3,055,300	3,055,300	2,764,100	2,618,500

The annual net cash flow is calculated as described in section 2.4. According to Eq. (18) the WACC is estimated to be equal to 5%. Finally, Eq. (12) gives a NPV equal to 36,532,000 EUR and IRR equal to 25.5%. As the NPV is positive and the IRR is greater than the discount rate, they indicate that, given the present data, it is profitable to invest in Lemnos. Finally, a sensitivity analysis was carried out in order to investigate the effect of the different financial inputs considered on the NPV and IRR. The financial parameters considered in the sensitivity analysis were the parameters related to the Initial Investment Costs and Operational Expenditures. Those parameters were not related to the site characteristics (such as Produced Energy and Municipal Taxes). The sensitivity analysis was performed in steps by assuming a change in a specific financial input equal to ±20% of its initial value as shown in Table 1. The corresponding results regarding the two metrics (NPV and IRR) are shown in the Tornado diagrams of Fig. 5. Regarding the initial investment costs, a change in the cost of Electromechanical Equipment has by far the greatest effect on both the NPV and the IRR than the other types of cost. Finally, in the case of annual operational expenditures, changes in the Maintenance costs have the greatest effects on the two metrics considered. It is evident that the results of the sensitivity analysis are in accordance with the contribution percentages of each type of costs as presented in Fig. 4.



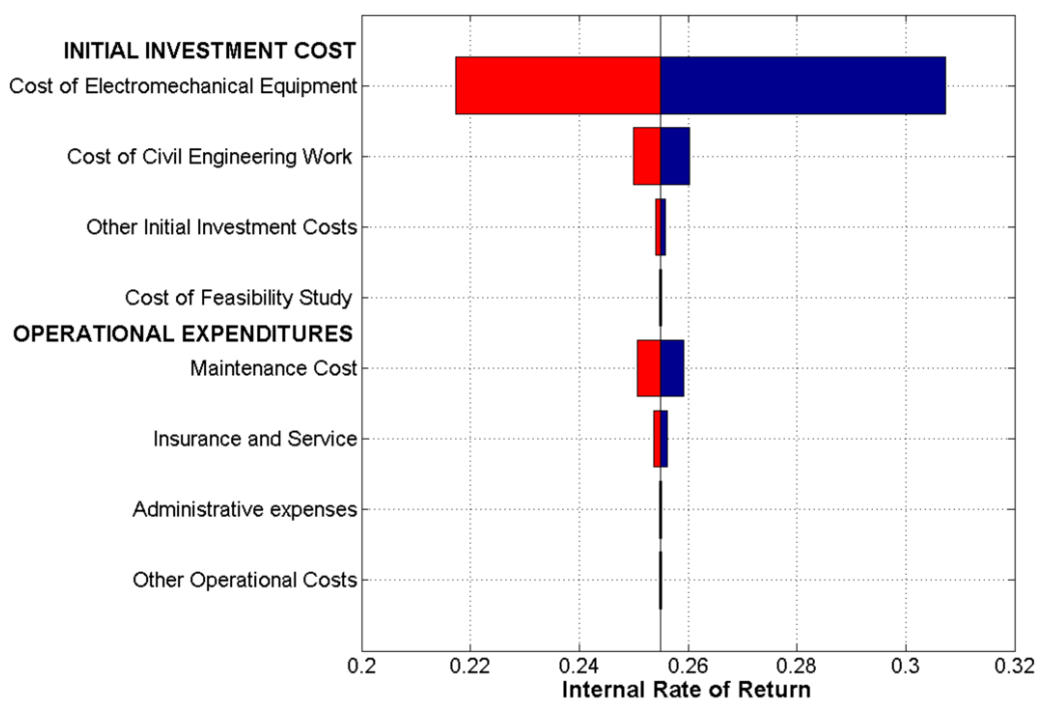


Fig. 5: Tornado diagrams for the sensitivity of the Net Present Value (top) and Internal Rate of Return (bottom) to ±20% changes in the financial input parameters considered in the case study of Lemnos.

4. Aggregated Results for Greece

The process described in section 3 was repeated for the data downloaded for all weather stations considered in this study. Fig. 6 shows the locations of the 285 weather stations, which cover most of Greece, with installation sites both on the mainland and on a large number of islands.

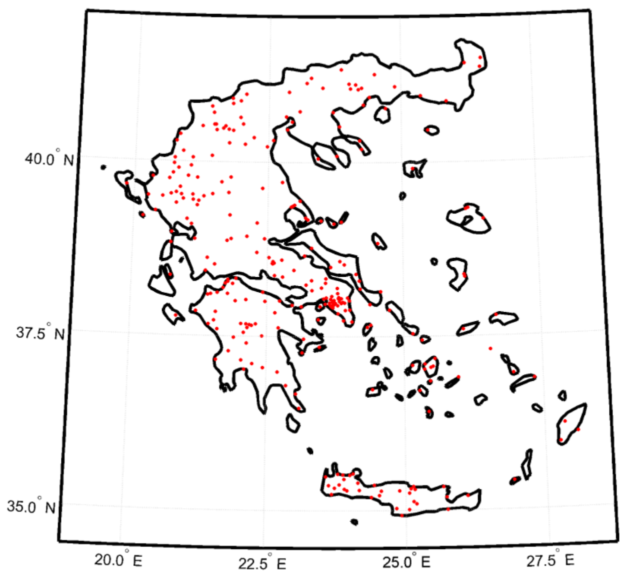


Fig. 6: Weather stations considered from the NOANET (2015) database

For each site, the assumption was made that the total initial investment cost, operating costs, fixed assets and depreciation are identical. The income is assumed to change from place to place since wind speed and thus energy production differ across the sites. Fig. 7 depicts the map of the average daily wind speed at hub height and the map of the annual produced energy as obtained by interpolating the corresponding values estimated for each of the weather stations. Moreover, the funding scheme differs across regions as the subsidy rate changes, according to the Incentive Zone (Table A.3 of the Appendix). The final step was to produce two contour maps of the NPV and the IRR by similarly interpolating of the individual site results (Fig. 8).

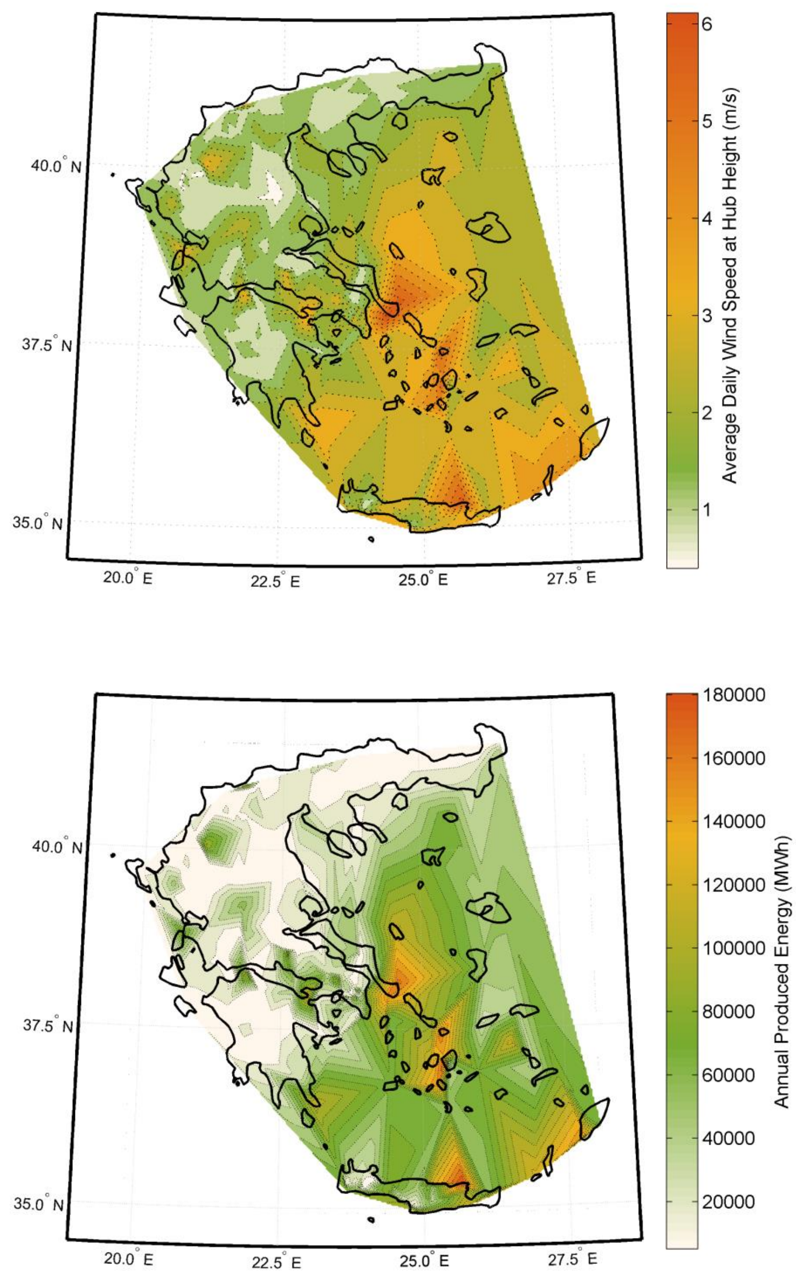
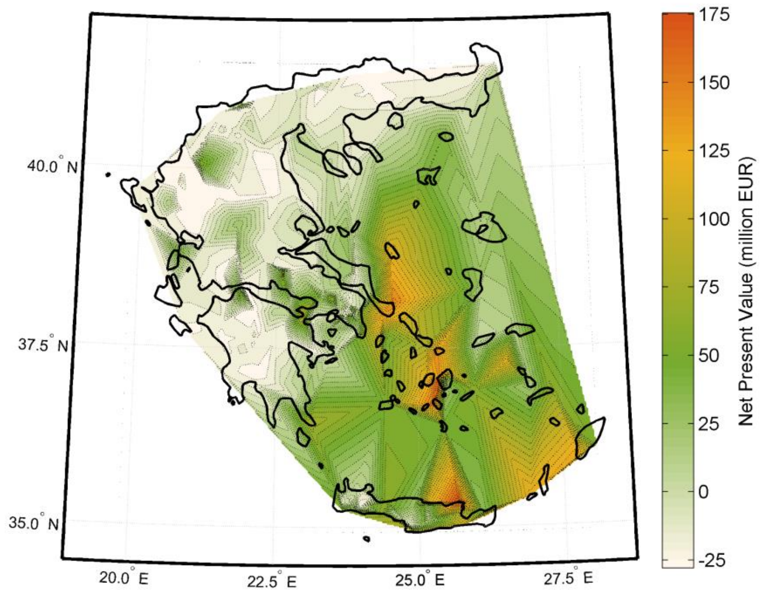


Fig. 7: Map of average daily wind speed at hub height of GE 3.2-130 in m/s (top). Map of annual produced energy (in MWh) by a wind farm of 32MW (bottom)



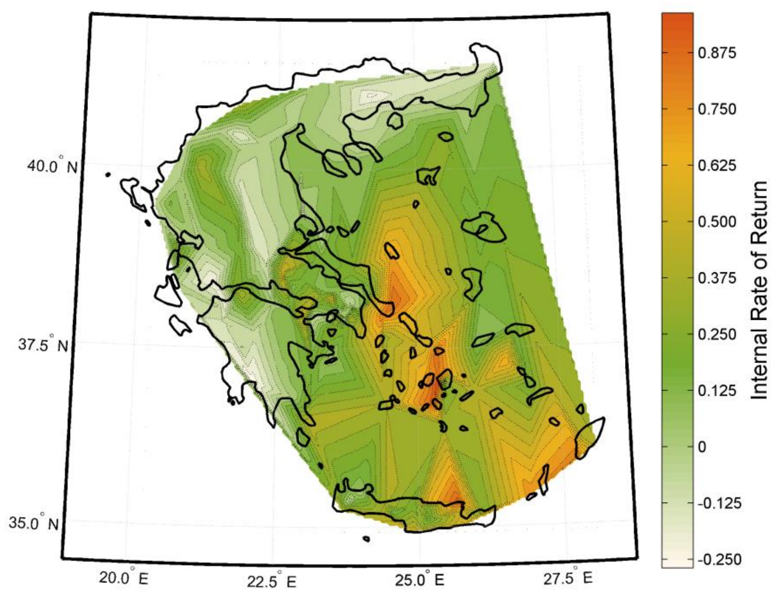


Fig. 8: Net Present Value (top) and Internal Rate of Return (bottom) for a 32 MW wind farm in Greece

Overall, both the NPV and IRR metrics reach the same conclusions. The areas which are most profitable for investing in a 32MW wind farm are depicted with orange color, while those in which the investment is not profitable are depicted in white. Green colors show areas where there is a medium profit and are mostly concentrated in the mainland. According to Fig. 7 and Fig. 8 wind speed of an area is the governing factor affecting the outcome of the investment in a wind farm project. This is inferred by the fact that all maps of Fig. 7 and Fig. 8 follow the same color pattern (i.e. the areas with high wind speeds are associated with high NPV and IRR).

The most profitable areas for investing in a wind farm in Greece are Cyclades islands, Dodecanese islands in South Aegean Sea and the islands in North Aegean Sea, South Rethymno, South Heraklio and north Lasithi in Crete, East coastlines regions of Lakonia in Peloponnese. Regions in which wind park investments should not be made are: Central Ilia, Central Messinia, Central Achaia, Central Arkadia, which are regions in central Peloponnese; Ioannina in Ipeiros; Grevena in Western Macedonia; Imathia, Pieria in Central Macedonia; Drama in Eastern Macedonia – Thrace. The results presented above are in accordance with several studies that have examined wind potential of Greek islands [7, 10].

5. Concluding Remarks

The optimal siting is investigated for an onshore wind farm of 32 MW in Greece by using the most comprehensive wind speed data that is publicly available. A feasibility study is conducted by applying two metrics, namely the Net Present Value (NPV) and the Internal Rate of Return (IRR) for examining the investment decisions. Expert opinion from local operators has been employed extensively to quantify important cost contributors, such as the cost of installation, operation and maintenance. Overall, both metrics show that the most profitable regions for investing in Greece are islands in the Aegean Sea and coastlines regions in South Central Greece, in East Peloponnese and in South Attica. On the other hand, investments are not profitable in regions of Central Peloponnese and in several regions of central mainland of Greece. The results are obviously sensitive to values that are subject to change, such as the government mandated wholesale price of renewable electricity and the incentives offered for specific areas of Greece by law, while profitability is heavily impacted by the initial cost of electromechanical equipment and the annual maintenance costs. Still, we expect that the results should remain indicative of the premium real estate for wind park siting, and offer a simple-to-follow guide for similar studies in the future.

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Appendix

Table A.1: Stations included and period of measurement in months

Station Name (ID)	months	Station Name (ID)	months	Station Name (ID)	months	Station Name (ID)	months
3-5pigadia (LGE8)	93	hydra (LGM3)	95	magouliana (LG8G)	25	rethymno (LG58)	133
aegina (LGY7)	54	ierapetra (LG95)	125	makrakomi (LGE7)	114	rio (LGH8)	107
aghiosnikolaos (LGJ9)	102	igoumenitsa (LG43)	138	markopoulo (LG45)	139	rizomata (LGO4)	89
agia (LGS8)	73	ikaria (LGI9)	107	marmaras (LGZ4)	52	sagaiika (LGA0)	86
agiakiriaki (LGP6)	80	imeros (LGM9)	91	maroussi (LGK0)	102	salamina (LG5G)	25
agiaparaskevi (LG0B)	42	imittos (LGO2)	63	mavrolithari (LGA6)	118	samaria (LGB4)	117
agioitheodoroi (LGU5)	62	ioannina (LG49)	137	mavropigi (LGZ9)	52	samariagorge (LGY1)	57
agpantes (LG7E)	32	ios (LGI0)	109	megalopoli (LGG5)	108	samos (LGF1)	115
agrinio (LGH9)	108	ioulida (LGP2)	73	metaxades (LGL2)	100	samothraki (LGC1)	112
aitoliko (LGC7)	118	ippokrateios (LGT8)	69	metaxochori (LGD7)	111	santorini (LGX5)	61
alagonia (LGU7)	67	iraklia (LGP5)	83	metsovo (LGO8)	86	sebronas (LG9D)	36
alexandroupolis (LGD8)	116	isthmos (LG85)	125	mikrivigla (LGO7)	74	seli (LG87)	120
alikianos (LGT4)	67	ithaki (LGB0)	118	mikrokampos (LG3D)	40	serres (LGW6)	62
alimos (LG5C)	39	kaimaktsalan (LG93)	112	milos (LGS0)	74	sessi (LG1A)	40
alonissos (LGN2)	93	kalamata (LG6A)	49	moires (LGI2)	107	setta (LGT7)	51
amfiloxia (LG9E)	30	kalampaka (LGW3)	65	molaoi (LGF8)	109	simonopetra (LG1E)	37
amorgos (LGT5)	71	kalampaki (LG4D)	40	molyvos (LGY5)	60	sindos (LG8C)	41
ampelokipoi (LGH5)	106	kalavryta (LGV7)	61	monemvasia (LG56)	125	sitia (LGM2)	97
anavyssos (LGS5)	70	kalymnos (LGG6)	107	monipaou (LG6B)	41	skiathos (LG24)	113
andritsaina (LG77)	127	kandanos (LG9G)	23	mykonos (LG66)	117	skopelos (LG80)	125
andros (LGN6)	87	kantza (LG99)	122	myriki (LGK8)	99	skyros (LGI1)	108
anogeia (LGB6)	121	kaparelli (LGJ7)	132	naxos (LGM0)	95	sparti (LGF7)	112
anoliosia (LGO0)	81	karpenisi (LGC9)	117	neamakri (LGN5)	92	spata (LGG2)	113
antikira (LGG8)	107	kasos (LGM5)	81	neamichaniona (LG7C)	39	spetses (LGS6)	73
apiranthos (LGV3)	67	kassandreia (LGO9)	86	neaperamos (LG4B)	44	spili (LG75)	127
apollonas (LGT0)	67	kastoria (LGC0)	116	neasmyrni (LGR0)	75	stavrakia (LG8B)	42
ardassa (LGJ4)	103	katarraktis (LGE0)	99	nemea (LGE1)	115	stemnitsa (LGS2)	76
arfara (LGU6)	65	katovlassia (LGP7)	88	neoskosmos (LGM8)	92	steni (LG81)	125
argos (LGT3)	71	kattavia (LGAC)	50	nevrokopi (LG48)	138	stratoni (LGJ1)	95
aridaia (LGO1)	86	kavala (LG5J)	17	nikaia (LG0F)	27	styra (LGC4)	117
arta (LG38)	140	kavodoro (LGR5)	73	notiopedio (LGS4)	107	tanagra (LG69)	130
askyfou (LGZ6)	53	kavomalias (LGB5)	110	oleni (LGD5)	117	tatoi (LG3B)	43
aspraggeloi (LGE4)	114	kea (LGE3)	114	olenia (LG91)	120	thasos (LG5B)	44
aspropirgos (LG9B)	41	kechroti (LG1C)	79	olympia (LGB3)	102	theodoriana (LGK2)	102
asprovalta (LGV8)	68	kerasia (LG5D)	40	orestiada (LG31)	142	theologos (LGO6)	86
athens (LGB9)	118	kerasovo (LGO5)	85	paleochora (LG36)	139	thessaloniki (LGR9)	77
athensmarina (LG2B)	43	kerkini (LGD9)	113	pallini (LG6E)	32	thiva (LG4G)	27
chalandritsa (LGA8)	57	kerkyra (LGJ2)	105	panachaiko (LGV6)	46	tinos (LGB8)	118
chalkida (LGO3)	87	kiato (LG8D)	38	panagopoula (LG2E)	27	triantafyllia (LG3H)	18
chania (LG25)	150	kifissia (LG6F)	41	papigo (LGK6)	91	trikala (LG57)	133
chaniacenter (LGN3)	92	kilkis (LG42)	138	paralia (LGB1)	59	trikalakorinthias (LGR1)	81
chios (LG4A)	48	kimisi (LGW8)	60	paramythia (LGF6)	112	tripoli (LG83)	102
chiostown (LG6C)	39	kleidi (LGP9)	74	parga (LGK9)	100	tristeno (LGD0)	116
damarionas (LGU1)	70	kleisoura (LGM1)	90	parnassos (LGF9)	66	tsamantas (LGV5)	51
derveni (LGV0)	61	kolympari (LG5H)	21	parnassos1950 (LGA4)	104	tsepelovo (LG0E)	29
derviziana (LGI3)	105	kompoti (LGD2)	116	paros (LG02)	104	tyria (LGM4)	95
didyma (LG5E)	34	koniskos (LGA1)	58	patissia (LGT6)	68	upatras (LGZ1)	53
didymoteicho (LGZ5)	51	konitsa (LG3A)	48	patmos (LG65)	128	uth_volos (LG7A)	45
dion (LG55)	131	kopaida (LG5A)	47	patra (LG84)	121	vagionia (LG7B)	42
dodoni (LGP4)	81	kopanaki (LGV2)	62	paximada (LGW7)	59	vari (LGZ2)	53
domokos (LGW5)	64	korinos (LG7H)	21	paxoi (LGN1)	93	variko (LGF0)	112
doxato (LGU8)	69	korydallos (LG3C)	43	penteli (LGX9)	60	vartholomio (LGB7)	113
drama (LGH6)	108	kos (LGX1)	63	perama (LG6D)	40	vasilitsa (LG82)	104
elati (LGK4)	81	kozani (LG7I)	14	peristeri (LGU0)	65	vateri (LG4H)	19
elefsina (LG4F)	30	krieza (LGY0)	60	pertouli (LGE2)	114	vatopedi (LGC2)	111
elos (LG2C)	42	kyriaki (LG3G)	25	pesta (LGK7)	99	vegoritida (LGE9)	108
embonas (LGAB)	50	lafkos (LGJ0)	39	petroupoli (LG9C)	37	velvento (LG6G)	24
falasarna (LGL9)	98	lagadas (LGA5)	117	pinia (LGG7)	57	vilia (LGR6)	71
faliro (LGS3)	74	lagadia (LGW9)	60	pirgos (LG59)	133	vlasti (LG98)	120
filiatra (LG8E)	31	lamia (LGV9)	64	plakias (LGT2)	70	volos (LG51)	139
finokalia (LG9A)	46	lampia (LGW9)	38	plastira (LGL7)	77	vourgareli (LGR8)	97
florina (LG63)	131	lappa (LG92)	119	platanias (LG3E)	33	vovoussa (LGN9)	119
fotolivos (LGZ8)	53	larissa (LGL6)	101	plikati (LGY9)	48	vrilissia (LG1D)	40
fragmapotamon (LGD4)	110	lavrio (LGD6)	116	polydroso (LGL0)	100	vytina (LGU9)	69

Table A.1: Stations included and period of measurement in months

Station Name (ID)	months	Station Name (ID)	months	Station Name (ID)	months	Station Name (ID)	months
fterolaka (LGL3)	53	lefkada (LGI7)	106	portaria (LGY2)	51	xanthi (LGC6)	113
gardiki (LGL4)	60	lefkochori (LGJ8)	102	portorafti (LGY6)	56	zagora (LGG3)	110
gavalou (LG4E)	114	lemnos (LGI5)	106	pramanta (LGP1)	78	zakynthos (LGN4)	92
geraki (LGX6)	59	lentas (LGP0)	79	prasino (LGR7)	23	zarakes (LGD3)	115
grammos (LGL8)	23	lesvos (LGI6)	103	preveza (LGK1)	102	zitsa (LGN0)	88
heraclion (LG30)	144	lesvos-thermi (LGJ3)	104	ptolemaida (LG26)	145		
heraclionport (LG61)	123	levidi (LG4C)	43	pyrathi (LG8A)	46		
heraclionwest (LGW2)	65	lindos (LGAA)	50	rafina (LGZ0)	50		

Table A.2: Parameters of 4-parameter Weibull function for each weather station

Station Name (ID)	c (m/s)	k	P_{oper}	$\mathrm{P}(v > v_{out})$	Station Name (ID)	c (m/s)	k	P_{oper}	$\mathrm{P}(v > v_{out})$
3-5pigadia (LGE8)	2.70	0.85	0.37	0.00	lindos (LGAA)	3.38	1.01	0.74	0.00
aegina (LGY7)	2.80	1.10	0.66	0.00	magouliana (LG8G)	1.14	0.98	0.39	0.00
aghiosnikolaos (LGJ9)	4.76	1.24	0.81	0.00	makrakomi (LGE7)	2.37	1.22	0.15	0.00
agia (LGS8)	0.84	0.94	0.14	0.00	markopoulo (LG45)	3.27	1.22	0.66	0.00
agiakiriaki (LGP6)	1.55	1.10	0.14	0.00	marmaras (LGZ4)	1.61	0.97	0.17	0.00
agiaparaskevi (LG0B)	1.72	1.17	0.52	0.00	maroussi (LGK0)	1.82	1.12	0.39	0.00
agioitheodoroi (LGU5)	1.11	0.95	0.45	0.00	mavrolithari (LGA6)	1.76	1.02	0.21	0.00
agpantes (LG7E)	1.57	1.10	0.17	0.00	mavropigi (LGZ9)	0.94	1.03	0.16	0.00
agrinio (LGH9)	1.56	1.02	0.18	0.00	megalopoli (LGG5)	1.16	0.97	0.15	0.00
aitoliko (LGC7)	1.59	0.93	0.19	0.00	metaxades (LGL2)	1.06	1.11	0.17	0.00
alagonia (LGU7)	1.17	1.22	0.04	0.00	metaxochori (LGD7)	2.18	1.10	0.52	0.00
alexandroupolis (LGD8)	2.31	1.00	0.41	0.00	metsovo (LGO8)	1.40	1.06	0.10	0.00
alikianos (LGT4)	1.62	1.05	0.70	0.00	mikrivigla (LGO7)	8.76	1.43	0.93	0.02
alimos (LG5C)	1.59	0.98	0.28	0.00	mikrokampos (LG3D)	1.01	0.90	0.34	0.00
alonissos (LGN2)	2.25	1.18	0.59	0.00	milos (LGS0)	3.39	1.28	0.77	0.00
amfiloxia (LG9E)	1.42	1.20	0.65	0.00	moires (LGI2)	1.17	1.04	0.15	0.00
amorgos (LGT5)	3.59	1.11	0.76	0.00	molaoi (LGF8)	1.72	1.06	0.65	0.00
ampelokipoi (LGH5)	1.23	1.14	0.21	0.00	molyvos (LGY5)	2.76	0.94	0.64	0.00
anavyssos (LGS5)	1.27	1.14	0.25	0.00	monemvasia (LG56)	3.67	1.13	0.68	0.00
andritsaina (LG77)	2.32	1.10	0.28	0.00	monipaou (LG6B)	2.36	1.02	0.46	0.00
andros (LGN6)	5.61	1.48	0.87	0.00	mykonos (LG66)	9.14	1.36	0.89	0.01
anogeia (LGB6)	2.79	1.21	0.69	0.00	myriki (LGK8)	3.36	1.12	0.51	0.00
anoliosia (LGO0)	2.41	1.14	0.72	0.00	naxos (LGM0)	6.66	1.29	0.92	0.01
antikira (LGG8)	4.32	1.19	0.69	0.00	neamakri (LGN5)	2.31	1.20	0.42	0.00
apiranthos (LGV3)	3.59	1.12	0.75	0.00	neamichaniona (LG7C)	2.14	1.10	0.71	0.00
apollonas (LGT0)	5.26	1.46	0.85	0.00	neaperamos (LG4B)	1.85	1.08	0.31	0.00
ardassa (LGJ4)	2.00	1.04	0.21	0.00	neasmyrni (LGR0)	1.49	1.22	0.21	0.00
arfara (LGU6)	1.74	1.08	0.02	0.00	nemea (LGE1)	1.28	1.07	0.26	0.00
argos (LGT3)	0.86	1.23	0.22	0.00	neoskosmos (LGM8)	2.46	1.24	0.28	0.00
aridaia (LGO1)	1.66	1.15	0.11	0.00	nevrokopi (LG48)	0.93	0.90	0.08	0.00
arta (LG38)	0.61	1.08	0.09	0.00	nikaia (LG0F)	2.46	1.22	0.73	0.00
askyfou (LGZ6)	4.02	1.17	0.59	0.00	notiopedio (LGS4)	1.54	1.08	0.24	0.00
aspraggeloi (LGE4)	2.23	0.99	0.38	0.00	oleni (LGD5)	1.54	1.00	0.07	0.00
aspropirgos (LG9B)	1.90	1.14	0.58	0.00	olenia (LG91)	1.97	0.96	0.16	0.00
asprovalta (LGV8)	2.16	1.01	0.22	0.00	olympia (LGB3)	1.73	1.02	0.10	0.00
athens (LGB9)	2.15	1.27	0.32	0.00	orestiada (LG31)	1.77	1.03	0.24	0.00
athensmarina (LG2B)	3.19	1.28	0.95	0.00	paleochora (LG36)	3.82	1.42	0.83	0.00
chalandritsa (LGA8)	2.24	0.93	0.83	0.00	pallini (LG6E)	2.30	1.25	0.65	0.00
chalkida (LGO3)	2.63	1.38	0.76	0.00	panachaiko (LGV6)	5.32	1.17	0.82	0.01
chania (LG25)	2.37	1.07	0.51	0.00	panagopoula (LG2E)	1.17	1.37	0.08	0.00
chaniacenter (LGN3)	1.52	0.99	0.40	0.00	papigo (LGK6)	0.97	1.03	0.02	0.00
chios (LG4A)	3.03	1.22	0.61	0.00	paralia (LGB1)	1.36	1.01	0.20	0.00
chiostown (LG6C)	2.96	1.41	0.78	0.00	paramythia (LGF6)	2.51	1.25	0.86	0.00
damarionas (LGU1)	1.75	1.12	0.39	0.00	parga (LGK9)	1.58	1.21	0.43	0.00
derveni (LGV0)	1.70	1.00	0.46	0.00	parnassos (LGF9)	5.55	1.11	0.58	0.02
derviziana (LGI3)	1.00	1.24	0.03	0.00	parnassos1950 (LGA4)	5.02	1.27	0.86	0.00
didyma (LG5E)	0.88	1.02	0.06	0.00	paros (LG02)	5.43	1.29	0.89	0.00
didymoteicho (LGZ5)	2.52	1.11	0.62	0.00	patissia (LGT6)	0.93	0.87	0.04	0.00
dion (LG55)	1.28	0.96	0.12	0.00	patmos (LG65)	5.27	1.35	0.87	0.00
dodoni (LGP4)	1.25	1.16	0.07	0.00	patra (LG84)	2.73	1.18	0.78	0.00
domokos (LGW5)	1.39	1.01	0.19	0.00	paximada (LGW7)	9.37	1.29	0.85	0.09
doxato (LGU8)	0.78	1.13	0.03	0.00	paxoi (LGN1)	1.59	1.14	0.21	0.00
drama (LGH6)	1.01	1.07	0.13	0.00	penteli (LGX9)	4.00	1.08	0.76	0.00
elati (LGK4)	1.11	1.32	0.07	0.00	perama (LG6D)	0.95	1.11	0.36	0.00
elefsina (LG4F)	2.34	1.08	0.63	0.00	peristeri (LGU0)	1.49	1.14	0.58	0.00
elos (LG2C)	1.57	1.25	0.17	0.00	pertouli (LGE2)	1.77	1.09	0.11	0.00
embonas (LGAB)	3.21	1.06	0.84	0.00	pesta (LGK7)	1.02	1.14	0.08	0.00
falasarna (LGL9)	3.18	1.14	0.79	0.00	petroupoli (LG9C)	2.06	1.25	0.57	0.00
faliro (LGS3)	1.24	1.05	0.19	0.00	pinia (LGG7)	2.06	0.99	0.20	0.00
filiatra (LG8E)	1.63	1.03	0.19	0.00	pirgos (LG59)	1.03	1.01	0.27	0.00
finokalia (LG9A)	9.53	1.64	0.94	0.02	plakias (LGT2)	4.98	1.06	0.69	0.00
florina (LG63)	1.35	1.06	0.17	0.00	plastira (LGL7)	3.59	1.00	0.60	0.00
fotolivos (LGZ8)	1.33	1.06	0.17	0.00	platanias (LG3E)	1.94	1.06	0.55	0.00
fragmapotamon (LGD4)	3.31	1.04	0.84	0.00	plikati (LGY9)	0.85	0.91	0.04	0.00
fterolaka (LGL3)	5.50	1.11	0.69	0.01	polydroso (LGL0)	1.67	0.98	0.05	0.00

Table A.2: Parameters of 4-parameter Weibull function for each weather station

Station Name (ID)	c (m/s)	k	P_{oper}	$\mathrm{P}(v > v_{out})$	Station Name (ID)	c (m/s)	k	P_{oper}	$\mathrm{P}(v > v_{out})$
gardiki (LGL4)	2.09	1.16	0.07	0.00	portaria (LGY2)	2.43	0.91	0.35	0.00
gavalou (LG4E)	0.85	1.14	0.01	0.00	portorafti (LGY6)	3.44	1.05	0.75	0.00
geraki (LGX6)	1.79	0.97	0.61	0.00	pramanta (LGP1)	1.59	1.04	0.07	0.00
grammos (LGL8)	2.74	0.94	0.21	0.00	prasino (LGR7)	4.38	1.20	0.82	0.00
heraclion (LG30)	2.83	1.13	0.69	0.00	preveza (LGK1)	1.93	1.09	0.29	0.00
heraclionport (LG61)	5.26	1.28	0.95	0.00	ptolemaida (LG26)	2.30	1.05	0.17	0.00
heraclionwest (LGW2)	3.24	1.16	0.76	0.00	pyrathi (LG8A)	2.52	1.32	0.76	0.00
hydra (LGM3)	2.61	1.02	0.27	0.00	rafina (LGZ0)	3.45	1.05	0.92	0.00
ierapetra (LG95)	5.45	1.37	0.93	0.00	rethymno (LG58)	3.88	1.08	0.80	0.00
igoumenitsa (LG43)	1.16	1.15	0.59	0.00	rio (LGH8)	3.68	1.44	0.89	0.00
ikaria (LGI9)	3.76	0.94	0.27	0.00	rizomata (LGO4)	1.26	1.22	0.68	0.00
imeros (LGM9)	1.88	1.05	0.32	0.00	sagaiika (LGA0)	1.76	1.00	0.35	0.00
imittos (LGO2)	3.47	1.23	0.82	0.00	salamina (LG5G)	1.83	1.11	0.45	0.00
ioannina (LG49)	1.33	1.10	0.06	0.00	samaria (LGB4)	3.13	1.11	0.62	0.00
ios (LGI0)	7.47	1.43	0.93	0.00	samariagorge (LGY1)	1.26	0.91	0.03	0.00
ioulida (LGP2)	5.56	1.26	0.76	0.00	samos (LGF1)	2.27	0.88	0.59	0.00
ippokrateios (LGT8)	0.60	0.87	0.01	0.00	samothraki (LGC1)	4.18	1.03	0.66	0.00
iraklia (LGP5)	2.44	1.31	0.75	0.00	santorini (LGX5)	2.97	1.32	0.83	0.00
isthmos (LG85)	5.29	1.28	0.92	0.00	sebronas (LG9D)	1.77	1.25	0.34	0.00
ithaki (LGB0)	2.17	1.20	0.33	0.00	seli (LG87)	2.03	1.12	0.52	0.00
kaimaktsalan (LG93)	4.75	1.13	0.81	0.00	serres (LGW6)	1.83	1.02	0.12	0.00
kalamata (LG6A)	1.38	0.82	0.20	0.00	sessi (LG1A)	4.33	0.99	0.51	0.00
kalampaka (LGW3)	0.71	1.07	0.04	0.00	setta (LGT7)	0.71	1.06	0.03	0.00
kalampaki (LG4D)	1.12	1.07	0.31	0.00	simonopetra (LG1E)	1.94	0.84	0.58	0.00
kalavryta (LGV7)	0.94	1.03	0.06	0.00	sindos (LG8C)	2.65	1.08	0.26	0.00
kalymnos (LGG6)	2.60	1.23	0.58	0.00	sitia (LGM2)	2.96	1.31	0.74	0.00
kandanos (LG9G)	2.20	1.18	0.42	0.00	skiathos (LG24)	2.75	1.14	0.49	0.00
kantza (LG99)	0.83	0.98	0.09	0.00	skopelos (LG80)	2.91	0.95	0.68	0.00
kaparelli (LGJ7)	4.90	1.06	0.53	0.00	skyros (LGI1)	5.24	1.42	0.90	0.00
karpenisi (LGC9)	1.04	1.10	0.07	0.00	sparti (LGF7)	1.11	1.11	0.27	0.00
kasos (LGM5)	6.06	1.19	0.89	0.01	spata (LGG2)	2.25	1.21	0.64	0.00
kassandreia (LGO9)	2.58	1.04	0.45	0.00	spetses (LGS6)	1.97	1.23	0.82	0.00
kastoria (LGC0)	1.23	1.04	0.09	0.00	spili (LG75)	2.28	1.33	0.64	0.00
katarraktis (LGE0)	1.78	1.08	0.15	0.00	stavrakia (LG8B)	3.74	1.06	0.78	0.00
katovlassia (LGP7)	0.91	0.93	0.07	0.00	stemnitsa (LGS2)	0.42	1.74	0.00	0.00
kattavia (LGAC)	6.52	1.80	0.90	0.00	steni (LG81)	3.62	1.09	0.49	0.00
kavala (LG5J)	0.59	1.17	0.03	0.00	stratoni (LGJ1)	1.68	1.06	0.19	0.00
kavodoro (LGR5)	9.70	1.40	0.88	0.03	styra (LGC4)	3.70	1.27	0.89	0.00
kavomalias (LGB5)	4.85	1.19	0.89	0.00	tanagra (LG69)	2.07	1.14	0.48	0.00
kea (LGE3)	3.47	1.18	0.66	0.00	tatoi (LG3B)	1.79	1.25	0.29	0.00
kechroti (LG1C)	1.37	1.21	0.17	0.00	thasos (LG5B)	1.57	0.96	0.51	0.00
kerasia (LG5D)	1.04	1.10	0.05	0.00	theodoriana (LGK2)	1.35	1.20	0.08	0.00
kerasovo (LGO5)	0.84	0.95	0.31	0.00	theologos (LGO6)	0.74	0.99	0.13	0.00
kerkini (LGD9)	1.09	1.00	0.04	0.00	thessaloniki (LGR9)	2.45	0.88	0.34	0.00
kerkyra (LGJ2)	1.64	1.08	0.20	0.00	thiva (LG4G)	1.76	1.02	0.55	0.00
kiato (LG8D)	1.87	0.98	0.72	0.00	tinos (LGB8)	4.90	1.33	0.72	0.00
kifissia (LG6F)	2.82	1.14	0.47	0.00	triantafyllia (LG3H)	0.70	1.31	0.28	0.00
kilkis (LG42)	1.57	0.86	0.40	0.00	trikala (LG57)	1.04	1.03	0.04	0.00
kimisi (LGW8)	2.77	1.06	0.36	0.00	trikalakorinthias (LGR1)	1.99	1.16	0.73	0.00
kleidi (LGP9)	1.54	1.18	0.81	0.00	tripoli (LG83)	0.97	1.09	0.05	0.00
kleisoura (LGM1)	2.21	1.13	0.32	0.00	tristeno (LGD0)	1.42	0.99	0.05	0.00
kolympari (LG5H)	1.72	0.98	0.75	0.00	tsamantas (LGV5)	1.55	0.96	0.15	0.00
kompoti (LGD2)	1.08	1.00	0.15	0.00	tsepelovo (LG0E)	0.54	1.41	0.01	0.00
koniskos (LGA1)	1.77	1.06	0.23	0.00	tyria (LGM4)	1.26	1.09	0.05	0.00
konitsa (LG3A)	1.14	0.97	0.06	0.00	upatras (LGZ1)	3.18	1.00	0.76	0.00
kopaida (LG5A)	2.13	1.04	0.61	0.00	uth_volos (LG7A)	1.85	1.08	0.64	0.00
kopanaki (LGV2)	1.09	1.02	0.20	0.00	vagionia (LG7B)	3.37	1.17	0.64	0.00
korinos (LG7H)	1.25	1.09	0.12	0.00	vari (LGZ2)	2.64	1.28	0.74	0.00
korydallos (LG3C)	1.46	1.40	0.30	0.00	variko (LGF0)	1.21	1.02	0.05	0.00
kos (LGX1)	3.62	1.47	0.82	0.00	vartholomio (LGB7)	1.50	1.03	0.18	0.00
kozani (LG7I)	1.95	1.08	0.43	0.00	vasilitsa (LG82)	5.16	1.07	0.76	0.00
krieza (LGY0)	2.73	1.16	0.59	0.00	vateri (LG4H)	2.04	1.14	0.65	0.00
kyriaki (LG3G)	1.94	1.20	0.52	0.00	vatopedi (LGC2)	1.60	1.02	0.38	0.00
lafkos (LGJ0)	1.52	1.05	0.28	0.00	vegoritida (LGE9)	1.26	0.97	0.11	0.00
lagadas (LGA5)	1.52	1.09	0.08	0.00	velvento (LG6G)	0.88	1.28	0.02	0.00
lagadia (LGW9)	1.73	0.90	0.12	0.00	vilia (LGR6)	2.50	1.27	0.76	0.00

Table A.2: Parameters of 4-parameter Weibull function for each weather station

Station Name (ID)	c (m/s)	k	P_{oper}	$\mathrm{P}(v > v_{out})$	Station Name (ID)	c (m/s)	k	P_{oper}	$\mathrm{P}(v > v_{out})$
lamia (LGV9)	0.93	1.19	0.28	0.00	vlasti (LG98)	1.43	1.12	0.14	0.00
lampia (LGW9)	1.12	0.94	0.08	0.00	volos (LG51)	1.84	1.00	0.17	0.00
lappa (LG92)	2.16	1.07	0.32	0.00	vourgareli (LGR8)	2.19	1.03	0.08	0.00
larissa (LGL6)	0.90	1.07	0.01	0.00	vovoussa (LGN9)	1.33	1.28	0.02	0.00
lavrio (LGD6)	4.01	1.16	0.80	0.00	vrilissia (LG1D)	1.67	1.19	0.40	0.00
lefkada (LGI7)	4.05	1.33	0.88	0.00	vytina (LGU9)	1.20	1.11	0.04	0.00
lefkochori (LGJ8)	1.42	1.04	0.04	0.00	xanthi (LGC6)	2.04	1.02	0.20	0.00
lemnos (LGI5)	3.98	1.15	0.67	0.00	zagora (LGG3)	1.39	1.02	0.13	0.00
lentas (LGP0)	4.57	1.36	0.92	0.00	zakynthos (LGN4)	1.37	1.06	0.09	0.00
lesvos (LGI6)	2.29	1.06	0.73	0.00	zarakes (LGD3)	2.45	1.15	0.66	0.00
lesvos-thermi (LGJ3)	3.36	1.09	0.66	0.00	zitsa (LGN0)	0.84	1.10	0.01	0.00
levidi (LG4C)	1.44	1.08	0.11	0.00					

Table A.3: Zones of incentives and rate of subsidy (from Law 3908/2011)

Region	Prefecture	Zone	Rate of subsidy Size of Business		
			Large	Medium	Small and very small
Southern Aegean Sea	Cyclades	C	15%	25%	35%
	Dodecanese	C	15%	25%	35%
Central Greece	Phthiotis	B	15%	25%	35%
	Phocis	B	20%	30%	40%
	Evia	B	15%	25%	35%
	Viotia	A	15%	20%	25%
	Evrytania	C	20%	30%	40%
Central Macedonia	Thessaloniki	B	30%	35%	40%
	Halkidiki	B	30%	35%	40%
	Kilkis	C	30%	40%	50%
	Pella	C	30%	40%	50%
	Imathia	C	30%	40%	50%
	Pieria	C	30%	40%	50%
	Serres	C	30%	40%	50%
West Macedonia	Grevena	C	30%	40%	50%
	Kozani	B	30%	35%	40%
	Florina	C	30%	40%	50%
	Kastoria	C	30%	40%	50%
Attica	Attica	A	15%	20%	25%
Thessaly	Larissa	B	30%	35%	40%
	Magnesia	B	30%	35%	40%
	Karditsa	C	30%	40%	50%
	Trikala	C	30%	40%	50%
Ionian	Corfu	C	30%	40%	50%
	Lefkada	C	30%	40%	50%
	Kefallinia	C	30%	40%	50%
	Zakynthos	C	30%	40%	50%
Crete	Heraklion	B	30%	35%	40%
	Chania	B	30%	35%	40%
	Lassithi	B	30%	35%	40%
	Rethymnon	B	30%	35%	40%
Peloponnese	Lakonia	C	30%	40%	50%
	Messinia	C	30%	40%	50%
	Corinthia	B	30%	35%	40%
	Arkadia	B	30%	35%	40%
	Argolida	B	30%	35%	40%
North Aegean	Lesvos	C	30%	40%	50%
	Chios	C	30%	40%	50%
	Samos	C	30%	40%	50%
Eastern Macedonia - Thrace	Kavala	C	40%	45%	50%
	Xanthi	C	40%	45%	50%
	Rodopi	C	40%	45%	50%
	Drama	C	40%	45%	50%
	Evros	C	40%	45%	50%
Ipeiros	Ioannina	C	40%	45%	50%
	Arta	C	40%	45%	50%
	Preveza	C	40%	45%	50%
	Thesprotia	C	40%	45%	50%
West Greece	Achaia	C	40%	45%	50%
	Aitoloakarnania	C	40%	45%	50%
	Ilia	C	40%	45%	50%