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MODELLING THE GREEN TRANSITION OF AG. EFSTRATIOS - ENERGY AND EMISSION ANALYSIS

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Introduction

The electrification of islands in Greece has been a challenging and expensive task with a significant carbon footprint. The reason is that the vast majority of the islands are not connected to the mainland electricity grid and rely on diesel engines for their electrification. Therefore, this practice emits significant amounts of CO2 and increases the production cost of electricity. Most big islands in Greece are gradually connecting to the mainland electricity grid, but some smaller island will remain without connection and for thee cases the green transition to RES is a necessary step for reducing the environmental impact and the cost of electricity production. This present study assesses the design that is officially proposed for the green transition of Agios Efstratios island. This plan includes the use of RES for addressing both the electricity and the thermal demand of the island. On the one hand, the proposed plan has excellent performance in respect to RES penetration and the reduction of the CO2 emissions. On the other hand, this present study addresses the excess electricity that is simulated to be produced from the proposed design. Modelling simulations with the software HOMER Pro are being utilized in order to calculate the exact amount of the excess electricity. The assessment of the available energy can be a useful first step for the future of planning of power-to-x or waste-to-x project that can potentially be coupled with the green transition project.

Materials and Methods

The island of Agios Efstratios (Ai Stratis) is located southeast from Limnos island and has only 270 permanent residents. At the moment, the electricity demand of the island is being met by mean of five diesel generators. Three of them have a nominal power output of 220 kW and two of the have a nominal power output of 90 kW. The scope of the green transition project is to install RES that would cover >85% of the total energy demand. For modeling purposes, the local climate data have been logged and utilized. In addition, the demand has been calculated by using data from the national public operator of the electrical grid.

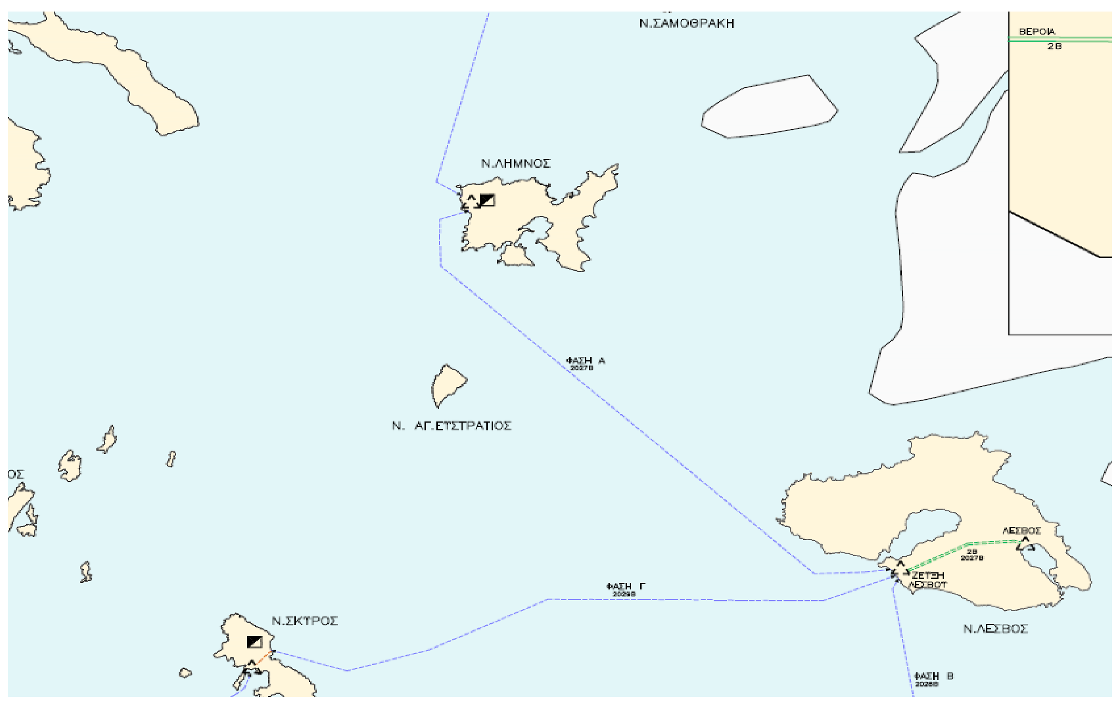

Fig. 1. Agios Efstratios will not be connected to the grid

The proposed RES design that will cover the electricity demand has been planned to have one wind turbine (950 kW), a set of Photovoltaic (PV) panels (150 kW) and lithium-ion battery storage system (2.5 MWh). Electricity produced from the previously mentioned system will power an electric thermal load controller that will cover the majority of the heat demand but will also be coupled with a conventional boiler. The diesel engines are expected to operate during peak demand and for relatively short periods of time.

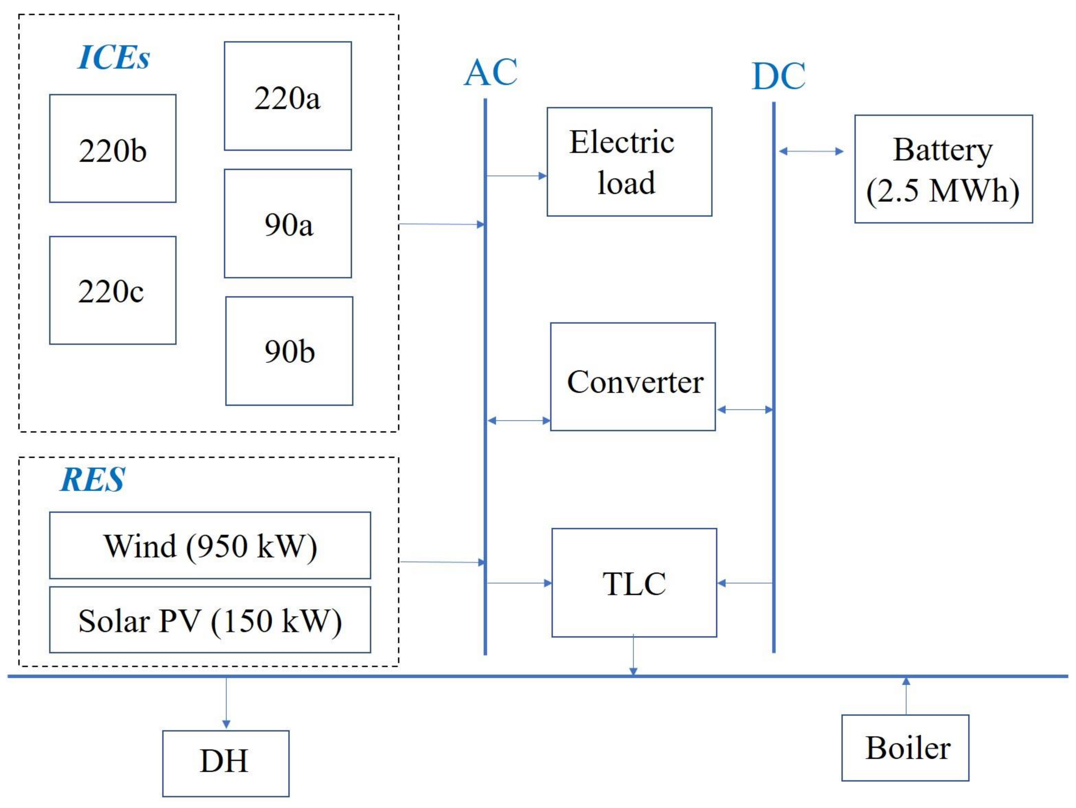

Fig. 2. Proposed design for the green transition

For the purposes of developing energy simulations for the current study the software HOMER Pro has been used. The software simulates all possible combinations of the various system components for an entire year and optimizes the system. Therefore, a follow-up study will assess alternative scenarios for different optimization strategies like the minimization of the emissions, the maximization of the RES penetration or the minimization of the net present cost that serves the desired load. Finally, sensitivity analysis projections can account for potential changes of the input of the system, such as fuel cost, wind speed or the price of batteries.

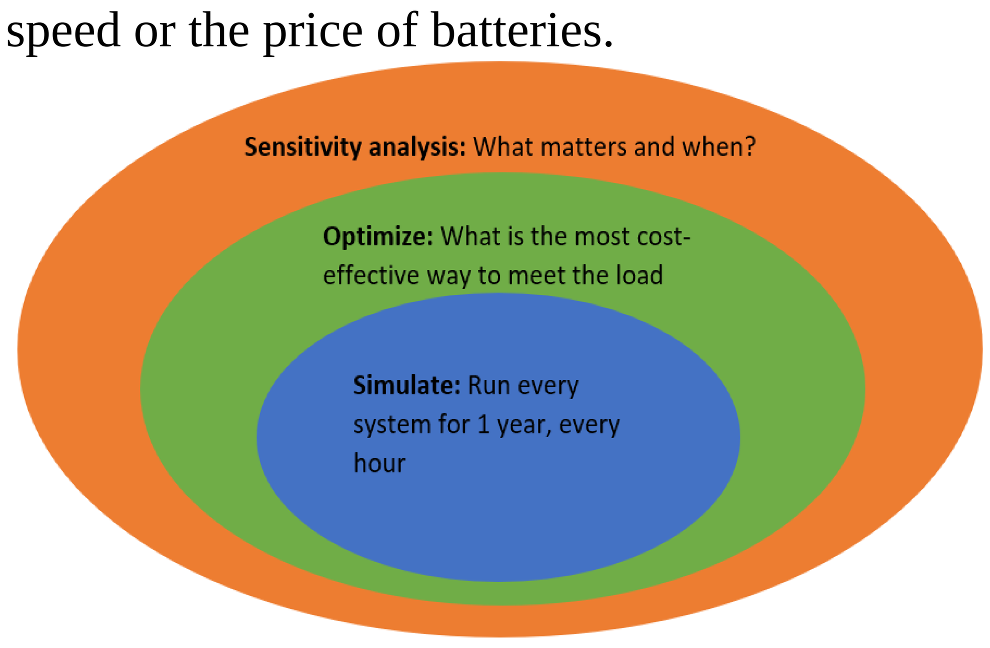

Fig. 3. The operational logic of HOMER Pro

Results and Discussion

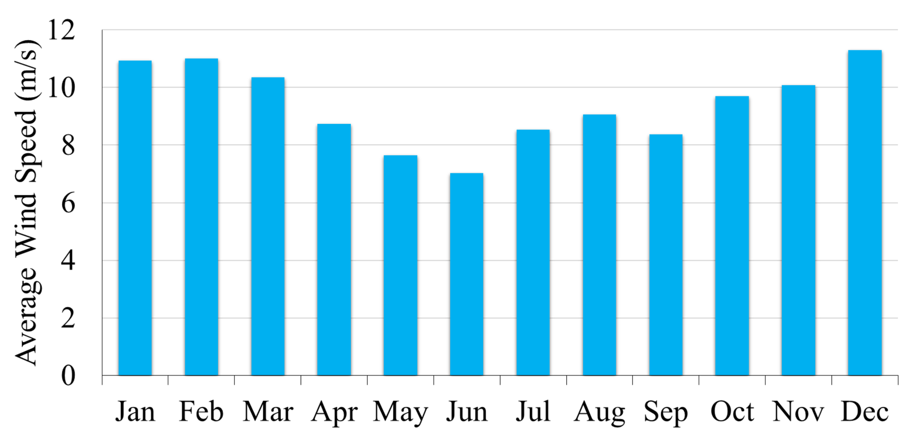

Fig. 4. Average monthly wind data

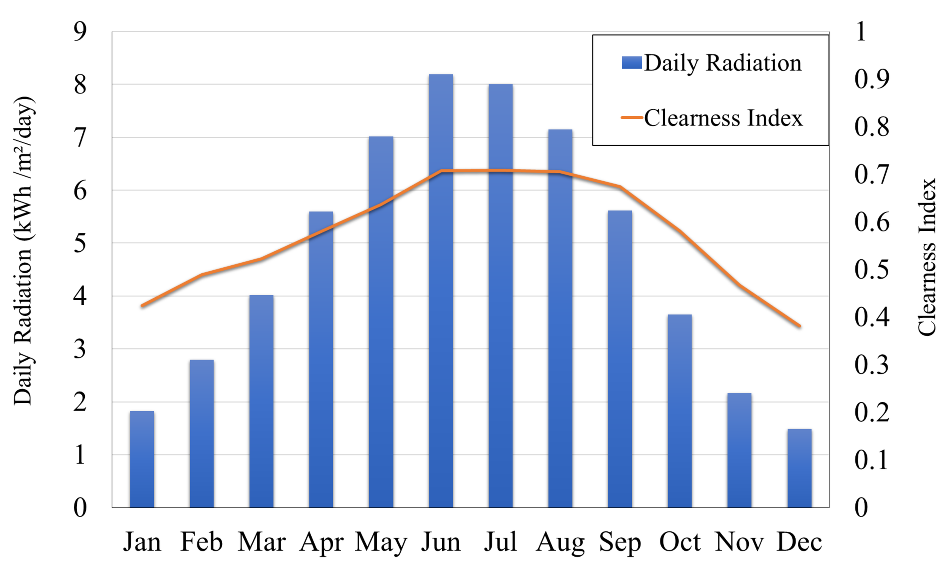

Fig. 5. Average monthly solar data

The average annual wind speed, according is 9.4 m/s, a value that was measured at the project site at 44 meters height. The average annual rainfall is at 451.7 mm and the data for the solar potential are retrieved from the NASA database.

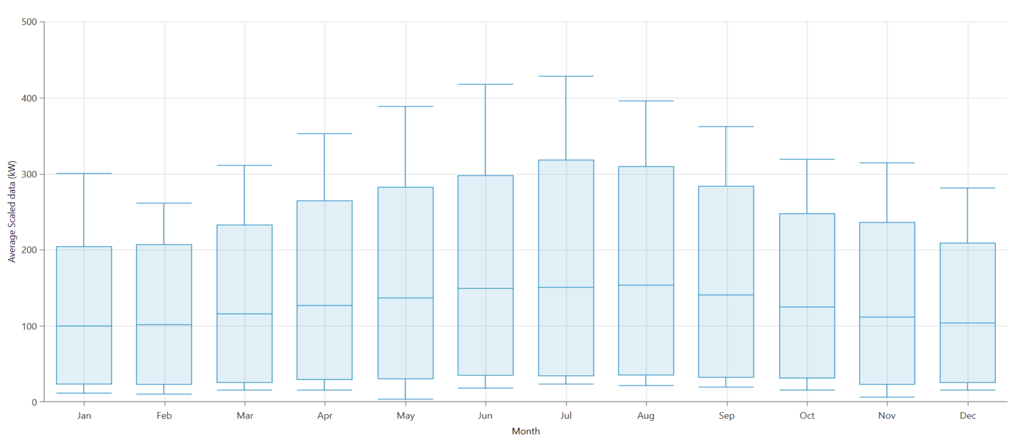

Fig. 6. Monthly electricity demand at Ag. Efstratios

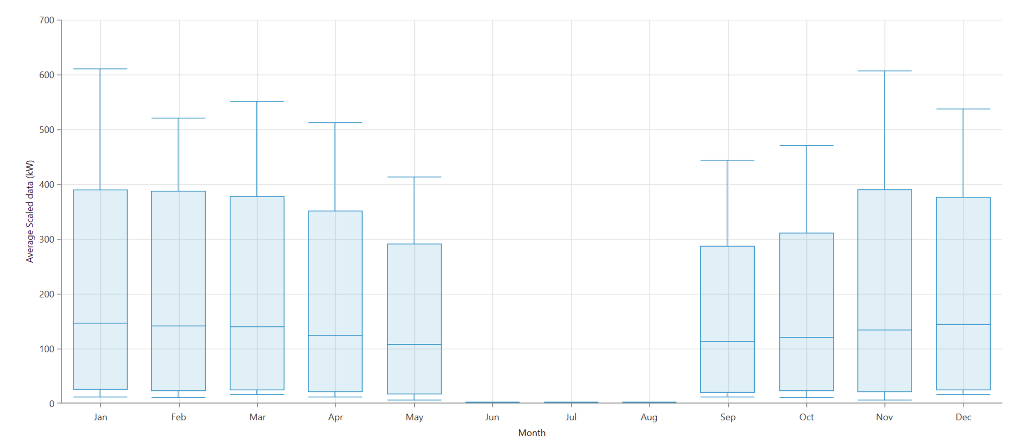

Fig. 7. Monthly thermal demand at Ag. Efstratios

The annual electrical demand of Agios Efstratios has been measured to be 1110.51 MWh, which corresponds to approximately 130 kW of power, but it should be mentioned that the load was measured at 428.15 kW. According to the public call of the green transition project the total thermal load is 856 MWh/year with a peak load at 482.73 kW.

Table 1. Simulated produced and excess electricity from the proposed design

Production	kWh/y	%
Enercon E-44 [900kW]	3,577,382	92.8
Canadian Solar CS6U-340M [150kW]	243,746	6.33
Gen220kW_a	4,260	0.111
Gen220kW_b	0	0
Gen220kW_c	0	0
Gen90kW_a	23,489	0.610
Gen 90kW_b	4,208	0.109
Consumption		
Total Electrical Load	1,109,965	100
Excess Electricity	**2,706,654**	**70.2**

The simulation returns a combined electricity production over 3800 MWh per year which is more than three times the annual demand. When the heat demand is accounted the value ratio of excess energy to used energy becomes more manageable but still approximately 2000 MWh remain available for other uses. It should be stated that in the overall energy balance are also accounted the kWh that are produced from the diesel engines during peak load. This aspect is crucial since the penetration of RES can not be 100%, unless the RES installations scale-up unreasonably, a practice that would be extremely costly. Nonetheless, the proposed design decreases impressively the CO2 emissions, from 1105 tons down to 123 tons.

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