Cost-Benefit Analysis for the installation and expansion of photovoltaic systems in non-interconnected islands in Greece

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Abstract. Due to environmental concerns about air pollution caused by burning fossil fuels to produce electricity, the use of solar energy, as a green and sustainable energy source, is of great interest leading to the rapid development of renewable energy sources (RES) such as wind, solar and biomass, which can provide reliable energy services and immediate benefits both nationally and locally. The main target of the present study is to investigate and analyze the Cost-Benefit (CBA) categories for the installation and expansion of photovoltaic systems in non-interconnected island regions in Greece and specifically on the island of Chalkis. To conduct the study, all available data were taken into account regarding the current RES legislation and policy of the European Union and the Greek Government and the current tariff for purchasing RES from the electricity company as well as the available solar potential of the island of Chalkis. Exemplary case studies, including a small-scale island system in the Aegean Sea, are examined in this context. The solutions must have minimal environmental impact, as these islands include protected areas of high ecological and biodiversity. The CBA analysis performed in this study focused on understanding economic sustainability and highlighting any positive and negative socio-economic impacts related to technological investment and implementation of renewable energy technologies. The results from CBA's evaluations highlight that the investment and implementation of the proposed technological solution are economically viable. In this way, the economic results alongside the social ones are positive both for the national economy and the private residents of the area.

Key-words: cost-benefit analysis (CBA), photovoltaic systems (PV), energy, non-interconnected islands (NIIs), renewable energy sources (RES).

1. Introduction

Going through the era of the global energy and environmental crisis, environmental planning becomes necessary to improve living standards through the utilization of RES. Photovoltaic systems are of particular interest, which in recent years have shown an upward trend in the European and international system. In an effort to support the development of renewable energy technologies, many nations, including Greece, have imposed national and international agreements binding them to their renewable energy targets over the years (Poullikkas, 2010). The solutions must have minimal environmental impact, as these islands include protected areas of high ecological and biodiversity.

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Today, in most Non-Interconnected Islands (NIIs) the cost of electricity generation is extremely high due to the use of outdated stand-alone power plants (APS) based on oil-fuel imports and diesel-electric generators. Since the interconnection of the remote islands with the mainland is not always cost-effective, the Hellenic Electricity Distribution Network Operator (DEDDIE) as responsible for the management and operation of the respective electricity systems, develops the necessary infrastructure for monitoring and control of the operation of all NIIs from the generation and grid side, in accordance with the provisions of the regulatory framework at present. (Chatziargyriou, 2016). This infrastructure will enable the optimal management of production, resulting in the maximum exploitation of RES, as well as objectivity and transparency in the operation of the market with the aim of very high levels of RES penetration (smart islands), which include the implementation of central storage facilities and intelligent management systems.

The present study aims to provide information through the economic cost-benefit analysis of the implementation of the Greek regulatory framework for a photovoltaic system and a suitable energy storage system for the electrification of small, remote island electrical networks. The purpose of this study is to investigate whether the installation of a Photovoltaic park in the area of Halki is economically viable through cost-benefit analysis (CBA). The research question that is developed in order to satisfy the research purpose of this research is related to the benefits and costs of the installation & expansion of photovoltaic systems in the NIIs and how beneficial is the development of the relevant investment.

2. Methodology

The main objective and the research question form the conceptual framework of the study and are the starting point for conducting the primary literature review related to the research question. Thus, scientific articles and studies related to the cost-benefit analysis in the case of RES and more specifically the use of photovoltaic systems were searched for. The bibliographic review carried out concerns studies of DEDDIE where it shows the margins of penetration and installation of photovoltaic systems in NIIs. Areas such as Tilos, Agios Efstratios, Ikaria, Halki are models for inclusion in the GR-eco Islands national initiative with the aim of covering energy needs through RES (DEDDIE, 2022b). Also, information about investments in corresponding PV systems in countries such as Kuwait and Pakistan highlighted the cost of the investment for the purchase of photovoltaic systems in addition to the benefit to the environment and the health of citizens. In order to establish whether the installation of a PV plant is economically and socially sustainable, a description of the investment plan is made regarding the construction of a photovoltaic power plant with a total power of 1MW on the Greek island of Chalkis, which belongs to the Dodecanese island complex of the southeast Aegean.

Also important is the contribution of the Electricity Innovation Lab, which gathered, after a relevant literature review, the main categories of costs and benefits related to the use of photovoltaic systems, since in this way the cost-benefit analysis for new studies, such as this one, is facilitated which is suggested here. According to the results of the e-LAB survey (2013), the main categories of benefits and costs, as well as their sub-categories, are the following:

Energy, the value of which is positive when the energy produced by photovoltaics is sufficient and it is not required to produce energy from other sources.

The financial risk.

Security, which refers to increasing the diversification of energy sources and creating backup energy sources through the combination of photovoltaic systems with transformers and battery devices.

The environmental value of the investment, which is positive when the use of photovoltaic systems reduces the environmental risks and also the health risks that would exist if it were not used.

Social value, which is positive when there, is a net increase in job opportunities and local economic development.

Thus, when conducting a CBA, the analyst's task is to estimate the changes in net social benefits resulting from the implementation of a project, which are derived from the difference between total consumer benefits and total producer costs and are directly related to changes in social

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surplus (Koopmans & Mouter, 2020). Also, it is useful to refer to the current situation regarding the production and consumption of energy in NIIs. To begin with, according to the production information sheet in the NIIs for August 2022, only 3.08% of the energy produced came from photovoltaics. Also, a very small percentage came from wind farms (7.49%) and the rest of the production was covered by conventional units (DEDDIE, 2022a).

3. Results

The main parameters to be calculated for project planning are: number and type of panels, initial cost, project lifetime, cost increase per year, cost increase due to age per year, energy generation rate. Also, a key parameter before starting the implementation process of the photovoltaic park is that the area of land where the construction will take place does not belong to a protected zone, for example a Natura area or a bird crossing corridor where the development of projects etc. is prohibited (Mosfilioti, 2020). Later, before starting the planning process of the project, a necessary condition is the collection of data through electricity bills, in the case where the study is carried out, that of the citizens of Halki, the needs of the island were calculated at 1,700 MWh per year on average, which makes the installation of the 1 MW photovoltaic park able to qualify Halki as the First Energy Autonomous Island in Greece.

The proposed photovoltaic park will have a capacity of 1MW and will be built on a plot of 15000 square meters. It will consist of 1998 photovoltaic panels that will each have a nominal power of 500 Wp. It is reported general information (installation degrees of PV panels, PV panels & inverters), as well as the results: generated power/year and the efficiency of the park. To complete the project it must be calculated how a photovoltaic park loses about 0.5% per year due to power assimilation. So if the first year produces €116,848, the 20th year of operation with the same weather conditions will produce €106,230. Accordingly, the first year of operation will give the DEDDIE network 1,797.67 MWh, while the 20th year of operation (always with the same weather conditions) will give the DEDDIE network 1,634.36 MWh.

The energy injected from the production of the PV Park into the DEDDIE network per year. The total production was calculated by subtracting 0.5% per year due to the power dissipation of the PV panels due to "hardware aging". The construction cost of the PV Park was €600,000 and the net profit per year. We can now say that the total cost of the investment over 20 years is €600,000 (construction cost) + €160,000 (Other annual costs maintenance) = €760,000. The calculation was made with an average price of €1.8/lt of oil, which may depend on the prevailing economic conditions, to change incrementally or downwardly.

In conclusion, it follows that over a 20-year period with a hypothetical average oil purchase price of €1.8/lt and the same generated power as the PV station of 1 MWp, the cost of purchasing oil amounts to €19,347,678.53. While with €760,000 a PV park has been built that produces the same energy without additional costs, simply from the sunshine. Therefore, the investment of the PV plant is amortized within the first year of operation. Even in the case of a contract with a large electricity supply between the state and the supplier, an excessively low purchase price would be achieved, for example that of 1€/lt of oil, with the result that the total cost of purchasing oil over a 20-year period would be €10,748,710.30. Therefore, the production benefit of the PV plant becomes profitable again.

4. Discussion

Cost benefit analysis (CBA) is the best way to evaluate the feasibility of a project, to lead to a correct and objective result by offering long-term analyses. The decision to approve or reject a project is made based on the comparison of benefits with costs (ADMIE, 2020). If the benefits are greater than the costs, then the project is profitable, while on the other hand, if the costs are greater than the benefits, the project is difficult to achieve. The main parameters to be calculated for project planning are: number and type of panels, initial cost, project lifetime, cost increase per year, cost increase due to age per year, energy generation rate. Also, a key parameter before starting the implementation process of the photovoltaic park is that the area of land where the construction will take place does not belong to a protected zone, for example a Natura area or a bird crossing corridor where

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5. Conclusions

The possibilities provided by the utilization of RES significantly change the sustainable development of the mainland. The main objective of this study was to investigate whether the installation of a PV park in the area of Halki is economically feasible through cost-benefit analysis (CBA). The study took into account the available solar potential of the island of Chalkis as well as all available data regarding the current RES policy of the European Union and the Greek Government and the current tariff for the purchase of RES from the electricity company. It therefore proves that RES, as an aid to the global energy and environmental problem faced by the modern era, contribute to more sustainable solutions. The contribution of photovoltaic systems brings economic benefits both in the industrial and construction sectors with the aim of sustainable development of society.

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