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Evaluation of future sustainable electricity generation alternatives: The case of a Greek island

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ABSTRACT

The decision-making process regarding the choice of alternative energy technologies is multidimensional, made up of a number of aspects at different levels, economic, technical, environmental and social. This paper uses a multicriteria decision making model, PROMETHEE II, to determine the best fuel mix for electricity generation in an isolated Greek island, Lesvos. Having analyzed the energy profile of the island, a set of 7 energy policy scenarios are determined and assessed against economic, technical, environmental and social criteria. The energy policy scenarios include the use of conventional fuels, wind energy and natural gas, in its liquid form, liquefied natural gas (LNG). Weighting of criteria is carried out according to three different perspectives, each one focusing on sustainability, economic and environmental/social benefits. Two sensitivity analyses are performed taking into account the fluctuations of the electricity demand and the fluctuations of the fuel prices.

1. Introduction

Sustainable development means the satisfaction of present needs without compromising the quality of life of future generations. Sustainable development has a dominant role in energy planning. Energy planning is the process of developing long-range policies for the future of a regional, national or even global energy system. It takes into consideration technical, political, social and environmental aspects and is carried out collecting the historical data of previous energy plans of the under examination region [1,2]. One of the most common problems of energy planning is to choose among various alternative energy sources and technologies in order to cover the energy demand. In some cases, decision makers face the dilemma of choosing among current and future conflicting goals of sustainable development, such as environmental degradation and energy security. This need to incorporate various aspects in energy planning, resulted in the increasing use of multicriteria approaches. Strantzali and Aravossis [3] showed in their literature review that the majority (almost 38% of the examined papers) of decision support papers, cover the application area of power generation technologies evaluation in regional and national energy planning. The classical outranking methods PROMETHEE and ELECTRE dominate in the preferences of decision makers in the research field of energy planning.

Energy planning in an island environment is complex and requires rigorous planning and appropriate tools of evaluation to aid in decision making. The important aspects are security of supply, economic viability, social acceptability and environmental protection. Specifically, in decentralized energy planning, the increasing interest in the utilization of models within the multicriteria analysis, indicates that these models provide better results during the energy supply systems planning process. Islands face specific problems, constraining their energy policies summarized by the following [4]:

- Connection to mainland production sources is impossible in the majority of cases, and the infrastructure for mainland interconnection is extremely expensive in other cases.
- A high level of dependence on imported fuel makes most islands highly vulnerable to fuel price fluctuations.
- There are numerous considerable demand fluctuations due to seasonal tourism.

Considering these limits, this paper uses a multicriteria decision making model, to determine the best fuel mix for electricity generation in a Greek island, Lesvos. It was found that the PROMETHEE II method is well adapted to this problem, since its flexibility enables the decision maker to express precisely his preferences and stable results can be easily obtained by sensitivity analysis. Greek islands cover their electricity needs mainly by heavy fuel oil (HFO) and light fuel oil (LFO),

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Nomenclature

LNG	Liquefied Natural Gas
NG	Natural Gas
HFO	Heavy Fuel Oil
LFO	Light Fuel Oil
APS	Autonomous Power Station
PPC	Public Power Corporation
$\Phi(X)$	Net flow of an alternative action X
Φ^+	Leaving flow
Φ^-	Entering flow
V_i	Values for criterion i
$V_{i\ max}$	Maximum value for criterion i
$V_{i\ min}$	Minimum value for criterion i
f_i	Preference function for criterion i
D_i	Difference function for criterion i
p_i	Preference threshold for criterion i
n	Number of alternative actions-scenarios
SCn	Scenario n
C	Criteria
LCOE	Levelised Cost of Electricity
$Investment_t$	Investment expenditure in year t
$O\&M_t$	Operation and Maintenance cost in year t
$Fuel_t$	Fuel expenditure in year t
$Electricity_t$	Electricity generation in year t
r	Discount rate
N	Number of criteria
W	Weight of criteria
$\overline{W}$	Average Weight
w	Relative Weight

with a small contribution of renewable energy plants (wind farms and photovoltaics). For the majority of isolated Greek islands, the interconnection to the mainland is challenging, due to the long distance from the mainland and the depth of the sea, whereas at the same time, their electricity demand faces fluctuations. It is expected that conventional fuels will keep their dominant role in their autonomous insular system, unless natural gas could replace them. The main scope of this paper is to investigate the possibility of natural gas penetration in the insular energy system of Lesvos as it is an alternative that researchers have not considered until now, and in parallel it is attempted an increase in the exploitation of renewable energy sources (RES).

The main steps relating to the formulation of the multicriteria problem for the sustainable energy planning in Lesvos, are outlined in Fig. 1.

The rest of the paper is organized as follows: Section 2 presents a literature review for energy planning studies in Greek islands, an overview of the background of the electricity system of the islands (and for Lesvos) and the current situation of natural gas penetration in Greece. Section 3 refers to the method used for the multicriteria analysis. Section 4 introduces the proposed sustainable energy policy scenarios for the island. Section 5 analyzes the criteria used and determines their values. In Section 6, the results from the application of the model are presented followed by Section 7 with the paper's conclusions.

2. Determination of the current energy system framework

2.1. Energy planning in Greek islands

One of the principal barriers that Greek islands face, is the energy balance of small capacity grids and the variable nature of power production, which does not necessarily correspond to the seasonal demands. The multidimensional problem of sustainable energy planning in Greek islands tried to face researchers in Table 1 using multicriteria analysis.

Kaldellis and Zafirakis [11] presented the current and future prospects of electricity generation in the Aegean Archipelago islands. Annual electricity consumption, peak power demand, capacity factor and specific fuel consumption are recorded for the years 1975 until 2005. It is, also, estimated the contribution of RES in the energy demand and the alternative of their interconnection with the mainland. Oikonomou et al. [12] studied the wind potential in the Dodecanese islands and identified the technological, environmental, social, economic and legislative barriers that face the RES projects. Georgiou et al. [13] examined the feasibility and the consequences of the interconnection of the Greek islands to the mainland grid. Various cost indicators (such as annualized investment cost, fixed and variable operation and maintenance cost, fuel cost, greenhouse gas (GHG) emissions, the cost of imported electricity and the cost of interconnections' development) have been considered. The study of the alternative power plants included different technologies: conventional and integrated gasification combined cycle (IGCC) lignite power stations, HFO conventional power station, LFO gas turbine power plant, HFO and LFO internal combustion engines (ICE), natural gas turbine power station, natural gas combined cycle (NGCC) power plant, mini, small and large hydroelectric stations, wind farms, photovoltaics (PV) parks and geothermal power plants plus biogas combined heat and power (CHP) plant.

2.2. Greek islands' electricity system

The Greek power sector consists of two subsystems, the main interconnected electric grid, that covers the mainland demand, and the insular power systems of Aegean islands. The Aegean Sea includes several hundreds of islands.

The majority of Aegean islands, with an exception for a few of them that are connected to the nearest mainland electrical network, are not connected to the mainland electricity grid. The electricity demand is covered almost exclusively by the existing Autonomous Power Stations (APS), based on internal combustion engines (running on Heavy Fuel Oil – HFO) and gas turbines (running on Light Diesel Oil), which owned from the Greek Public Power Corporation (PPC). Almost all the islands have high RES potential: wind, solar, biomass and geothermal [8].

In islands, the stability of the electrical system is sensitive to rapid variations of the peak loads, while at the same time the importance of self-reliance is evidently higher in comparison with a large connected system. These conditions limit the maximum load provided by energy

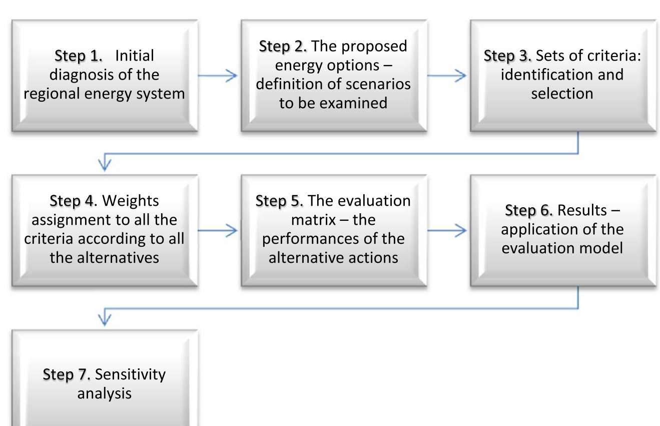

Fig. 1. The steps of the formulation of the problem.

Table 1
Literature review-MCDA case studies in Greek islands.

	Authors	Energy type	Case study	Criteria
1	Georgopoulou et al. [5]	8 Strategies (among them: Interconnection with the mainland, Conventional power station, Wind energy, Biomass, Solar thermal power plants, Hydro plants)	Crete	Investment cost, Operation and maintenance cost, Safety in covering peak load demand, Operationality, Stability of the network, Cohesion to local economic activities, Regional employment, Air quality, Noise, Visual amenity, Depletion of finite energy sources, Risk of climate change, Ecosystem's protection, Land use, Implementation of EU environmental policy
2	Haralambopoulos and Polatidis [6]	Geothermal resources	Chios	Conventional energy saved, Return of investment, Number of jobs created, Environmental pressures, Entrepreneurial risk of investment
3	Koroneos et al. [7]	Conventional system, Solar collectors, Wind turbines, Biomass, Geothermy	Lesvos	Equivalent CO_2, cost
4	Papadopoulos and Karagiannidis [8]	Oil-fired system, Wind energy, Solar energy, Biomass	Karpathos and Kassos	Net present value (NPV), Depreciated payback period (DPB), Life cycle cost (LCC), CO_2 emissions, Cost of covering the peak loads
5	Tsoutsos et al. [9]	Wind farms, PV systems, Olive kernel units, Oilstone biomass	Crete	Investment, operating and maintenance cost, Conventional fuels savings, Maturity of technology, Safety of supply, Environmental and social criteria, CO_2 emissions avoided, Contribution to local development and welfare, Social acceptance and viability of the remaining environmental effects
6	Mourmouris and Potolias [10]	Wind energy, Biomass, Solar energy	Thassos	Economic benefits for the region, Employment in the energy sector, Creation of development, Land used, Social acceptability, Environmental quality, Visual impacts, Impacts on flora/fauna, CO_2, SO_2, NO_x emissions, Efficiency, Safety, Availability

systems that are not continuously in operation, like the technologies utilizing RES, since sudden variations may lead to a break-down of the local distribution grid [8].

The alternative of converting the existing power engines or install new power plants that will operate on natural gas instead of HFO, seems to be a very interesting challenge. As the islands, cannot be connected with the mainland natural gas pipelines, they can, only, be fed with natural gas in its liquid form, Liquefied Natural Gas (LNG), from LNG carriers. The option of installing a small-scale LNG terminal on the island is challenging due to the land use needed. These types of investments are capital intensive and the results obtained from the present research will indicate if they are worth. Furthermore, the alternative of natural gas as combustion fuel in an insular power plant has not been evaluated by the researchers so far. At the same time, the exploitation of the RES potential of an island would result to a sustainable solution for its isolated electricity generation system.

2.3. Liquefied Natural Gas (LNG)

Liquefied Natural Gas (LNG) is natural gas that has been converted to liquid form for ease of storage as it is an efficient method of transporting overseas. It is condensed into liquid by cooling it to −162 °C, close to the atmospheric pressure. The dominant component of natural gas is methane with some mixture of ethane and small amounts of heavy hydrocarbons. It is a fossil fuel, but it can be mixed with, or replaced by biogas, which also consists mainly of methane. Natural gas is lighter than air and has a narrow flammability interval. It has a high auto ignition temperature and it needs an additional ignition source (named: a pilot fuel), in order to ignite in combustion engines. Natural Gas (NG) is a clean and non-sulphurous fuel. The gas engines have been proven to be reliable. Exhaust emissions such as SO_2 and PM are negligible. NO_X can be reduced by approximately 80–90% for Otto cycle processes, and 10–20% for Diesel cycle processes [14].

Natural gas contains less carbon than fuel oils. It could be considered the most environmentally friendly fossil fuel, because it has the lowest CO_2 emissions per unit of energy and because it is suitable for use in high efficiency power stations. For an equivalent amount of heat, burning natural gas produces about 30% less CO_2 than burning petroleum and about 45% less than burning coal [15].

Natural gas can be used in dual fuel engines being able to run on either liquid fuel oils or gaseous fuel. Such engines can be either two stroke diesel engines or four stroke engines and their working principle is based on Otto cycle when operating on natural gas, and on Diesel cycle when operating on fuel oils. The pilot fuel is a small amount of fuel oil which is injected and ignited by the compression heat and the burning oil ignites the gas [14].

Due to the low temperature of storage, LNG must be stored in cryogenic tanks. LNG storage tanks require more space than traditional fuel oil tanks, due to the lower LNG density. To ensure safe and reliable operation, particular measures are taken in design, construction and operation. In its liquid phase, LNG is not explosive and cannot burn. It must first be vaporized, and then mixed with air in the proper proportions to be ignited. In the case of a leak, LNG vaporizes rapidly, turning into a gas and mixing with air.

2.4. Existing LNG infrastructure in Greece

Fig. 2 shows the Greek Natural Gas transportation network. Roughly three-quarters of gas is supplied from Russia and Turkey by pipeline, and the remaining portion is imported in the form of LNG, largely from Algeria. The transmission system operator (TSO), DESFA, plays a major role in emergency planning and managing crisis situations [16].

The map shows the current points of LNG availability and the possible points of LNG availability in the future. It is clear that Piraeus port is the one closest to an LNG facility, the Revithoussa Island.

Fig. 2. Natural Gas transportation network in Greece [18].

Revithoussa is a small island located 45 km west of Athens.

Revithoussa Island is the entry point of natural gas in Greece and is the most equipped and continuously invested plant in the country. Revithoussa import LNG terminal is equipped with 2×65,000 m^3 tanks and a 95,000 m^3 tank is under construction. This would most likely also develop an export bunkering reload facility (for trucks and small LNG Carriers).

The rest of the locations are either where a natural gas line will pass in the next 20 years or where a LNG liquefaction plant is most likely to be built. For example, Patras port at Achaia Northern Peloponnesus, that provides routes between the main islands of Ionian Sea and connection between Patras port and Italy ports, is a location that any natural gas related investment has not been announced not even as a proposal, thus making the presence of LNG in the future unknown. On the other hand, South Stream and TAP will pass close to north Ionian Sea.

Two more import LNG terminals have been proposed in Alexandroupolis and in Kavala (170,000 m^3 each) at North Aegean Sea but no export terminal has been proposed so far [17].

2.5. Lesvos island

The island of Lesvos is located in the northeastern Aegean Sea with an area of 1636 km^2 and a population of 85,330.

The insular electricity system of Lesvos is a typical example of how to cope with the problem of planning a decentralized energy system. The electricity system of the island comprises one heavy fuel oil power plant located in Mytilene. The plant reaches a nominal capacity of 92.5 MW and the peak demand registered in 2014 was 63.69 MW and in 2013, 63.87 MW [19]. The PPC plans to replace a part of the existing combustion engines in the near future with the installation of two or three new generators (nominal capacity of 12 MW each one). In a longer term, PPC plans to design a new power plant in the island.

Fig. 3 shows in MWh the electricity consumption in 2015 from the different power plants located in the island. It is observed that the highest electricity demand occurs during the summer and winter seasons, with the highest consumption during August. The total requirement of electric energy on the island is estimated to be 296.6 GWh/year (for 2015, which was the highest electric energy demand for the last three years, Fig. 4). The renewable electric energy is primarily

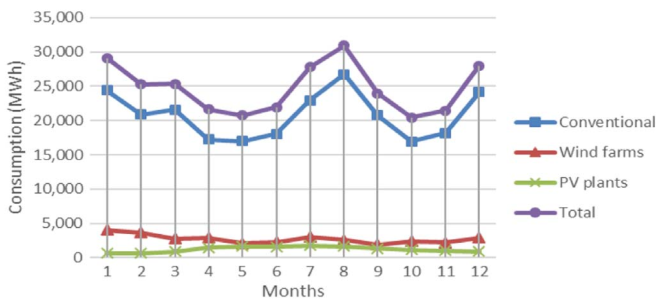

Fig. 3. The monthly energy consumption in 2015 [19].

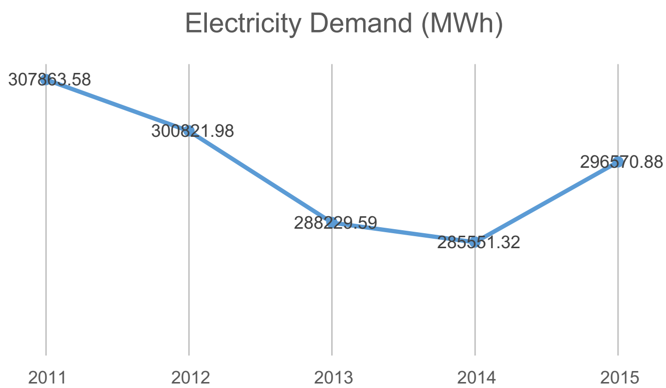

Fig. 4. The electricity demand in the island for the last five years [19].

produced by wind energy installations and PV installations [19].

The RES power generation covers almost 16% of the total requirements. More specifically, the wind energy production installations have a total installed power of 13.95 MW. Moreover, certain PV systems are installed, 8.84 MW, and cover a small percentage (only 5%) of the demand. The study focused on the consumption of the last three years (2013, 2014, 2015), because only these years include all the current installations of wind farms and photovoltaics, and so their contribution to the total energy production is similar [19]. The analysis is based on the electricity consumption of 2015 (the year with the highest electricity demand in the last three years) and a sensitivity analysis is carried out. Potentially, 30% of total required energy could be covered from RES, and consequently the objective is to cover the remaining 14% from RES, which equals to 41.2 GWh/year. This supplement energy supply percentage of RES could be covered by wind farms.

3. Multicriteria analysis

Multi-Criteria Decision Making (MCDM) techniques are popular in sustainable energy management. The techniques provide solutions to the problems involving conflicting and multiple objectives. Several methods based on weighted averages, priority setting, outranking, fuzzy principles and their combinations are employed for energy planning decisions [3]. Applications of MCDM include areas such as energy policy analysis, electric power planning, technology choice and project appraisal, and environmental impact analysis [3,20].

During the last decade, the outranking methods have known a rapid development and they have been considered suitable for such problems, with Electre (Elimination and choice translating reality) and Promethee (Preference Ranking Organization Method for Enrichment Evaluation) being two of the most widely applied outranking methods [21]. The Promethee II method has all the advantages of the outranking methods, combined with the simplicity of use and decreased complexity [22]. As a result, Promethee II was selected to be used in this study.

PROMETHEE is a multi-criteria decision making method developed by Brans et al. [23]. It is well adapted to problems where a finite number of alternatives are to be ranked considering several conflicting criteria.

With Promethee, alternatives are compared in pairs for each criterion. The suggested alternative actions are compared in pair and the outcome is presented in an evaluation matrix. A number in the interval [0; 1] (zero for no preference or indifference, unity for strict preference) expresses the preference level. A multicriteria preference index is formed for each pair of alternative action X (here called Scenario n, "SCn") as a weighted average of the corresponding preferences computed in the last step for each criterion. The weighting factors express the relative importance assigned to each criterion. Alternative actions can be ranked by a positive or a negative flow. The "leaving flow" $\Phi^+(X)$ indicates preference of an alternative action X over all the other actions. It shows how "good" the alternative is; the alternative with the higher leaving flow is superior. The "entering flow" $\Phi^-(X)$ indicates preference of all other actions compared to X [24].

In PROMETHEE II, the net flow is computed by taking the difference of leaving minus entering flows which permit a complete ranking of all alternatives (higher is better).

$$\text{Net Flow } \Phi(X) = \Phi^+(X) - \Phi^-(X) \tag{1}$$

First and foremost, it is calculated the values, $V_i(X)$, of each alternative action X for each criterion i (here Table 8). After the determination of the values $V_i(X)$, the indicator of preference is calculated. The calculation is conducted with the help of a preference function $f_i(X, Y)$, which is an interrelation of the difference of values $V_i(X)$ and $V_i(Y)$ of the alternative actions X and Y respectively, that is to say:

$$f_i(X, Y) = f_i(V_i(X) - V_i(Y)) = f_i(D_i(X, Y)), \tag{2}$$

where

$$D_i(X, Y) = V_i(X) - V_i(Y). \tag{3}$$

The use of indifference and preference thresholds facilitates decision makers expressing their preferences for their criteria.

It is used an empirical rule for the estimation of indifference thresholds, which is the calculation of percentages on maximum difference ($Vi_{max}-Vi_{min}$) of the values $V_i(X)$ for each criterion i and for each alternative action X. Often, the indifference threshold is estimated: 5–15%, and the preference threshold: 10–30% of this difference. Alternatively, the preference threshold could be calculated by the function, $p_i=(Vi_{max}-Vi_{min})/n$, where n is the number of alternative actions. In most energy planning methods, the indifference threshold is regarded as equal to zero [9].

For simplification, in the present study, the indifference threshold has been ignored, and the V-type preference equation has been used for the quantitative criteria. The "usual" type of preference equation has been used for the qualitative criteria.

The implemented model could be summarized by the following steps: After the determination of the alternative actions – Scenarios – for the satisfaction of the electricity demand in Lesvos, the values $V_i(SCn)$ for each criterion i, were calculated (Table 8). Then, the selected criteria are weighted focusing in different areas (here called "Strategies") arising from different hierarchy of preferences. Except from the results obtained from the above described analysis, the present model includes, also, two sensitivity analyses, one for the fluctuations in electricity demand and the other for the fuel prices (the alternatives arising from different fuel prices are called "Cases" in the study). Finally, the results have been compared and analyzed.

4. Energy policy scenarios

Koroneos et al. [7] examined different scenarios for the coverage of the energy needs of Lesvos, using a multi-objective optimization methodology. Their alternative scenarios included the satisfaction of the electricity needs with the use of photovoltaics, wind turbines and the existing conventional system, while the thermal needs could be satisfied with geothermal energy, biomass combustion and the existing conventional system. Their evaluation criteria were, only, CO_2 emissions and cost. Their results concluded that the wind turbines could be used to cover the electricity demands, the solar collectors could satisfy the needs of hot water, and geothermal energy and biomass could cover the space heating demands.

The continuation of the operation of the existing conventional system will increase the pollutant emissions more and more in the future. On the other hand, Lesvos electricity system is isolated and needs a stable power plant in order to cover peak demands. This study focuses to the satisfaction of the electricity demands of the island, switching from conventional fuels (HFO) to natural gas and the benefits that will occur to the environment and the local habitants. The option of utilizing RES, mainly wind energy that is abundant, to cover a percentage of the base load demand throughout the year, while using the conventional power station, which can be converted to burn natural gas, for the remaining part of the base load and the seasonal peak demand, may be a very sound alternative and has not been evaluated by researchers so far. The alternative of solar energy is excluded from the current study, as the current legislation promotes the residential installations, and the economic benefits from a large scale installation are prohibitive for the stakeholders.

According to the Greek Law 2464/08, the maximum wind energy penetration for the Greek isolated islands cannot exceed the twice of their peak load, for reasons of stability of the local grids. In the case of the current study, this limit will not be exceeded.

The energy policy scenarios selected, are these ones that are more feasible to achieve the goal of sustainable electricity supply for Lesvos in the near future. In the base case scenario, the existing oil-fired system should switch its fuel from HFO to Low Sulphur HFO (LSHFO) in order to comply with the EU Directives 2010/75 [25] and 2015/2193 [26] for SO_2 emission limits in combustion power plants. Directives 2010/75 and 2015/2193 lay down strict rules to control emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust into the air from combustion plants, and thereby reduce emissions to air and the potential risks to human health and the environment from such emissions. For the existing combustion plants, the emission limits will be applied from 1st January 2025, and for new combustion plants will be applied from 1st January 2018. Thus, the scenario of keeping the current combustion fuel, HFO, is not included in the study. HFO will be replaced by Low Sulphur HFO (LSHFO), which has lower percentage of Sulphur.

The following energy policy scenarios are proposed:

Base case ("Base")

The Base case scenario refers to keeping the current oil-fired system with replacement of HFO fuel with LSHFO.

Scenario 1 ("SC1"): 30% wind energy penetration

A percentage of 30% of the total required energy will be covered from wind farms. The 16% is, already, installed and so it remains the 14% which is equal to 16 MW (i.e. 8 wind generators 2 MW).

Scenario 2 ("SC2"): 50% wind energy penetration

A percentage of 50% of the total required energy will be covered from wind farms. The 16% is, already, installed and so it remains the 34% which is equal to 36 MW (i.e. 18 wind generators 2 MW).

Scenario 3 ("SC3"): Replacement of the old engines (Natural gas)

This alternative includes the replacement some of the obsolete combustion engines with new dual fuel engines, which could operate on fuel oil or natural gas. It is planned by the utility operator, 3 new dual fuel engines to be installed (technical data needed for calculating the fuel consumption of the engines are retrieved from [27]).

Scenario 4 ("SC4"): Replacement of the old engines (Natural gas)+30% Wind energy penetration.

The fourth alternative adds to the third alternative the coverage of 30% of the total required energy from wind energy (as in Scenario 1).

Scenario 5 ("SC5"): New Power plant (Natural gas)

The fifth alternative includes the installation of a new power plant (i.e. 90 MW) with dual fuel engines in order to replace the existing.

Scenario 6 ("SC6"): New Power plant (Natural gas)+30% Wind energy penetration

The sixth alternative adds to the fifth scenario the coverage of 30% of the total required energy from wind energy (as in Scenario 1).

All scenarios consider the energy demand in MWh, which represent the actual demand, not the nominal capacity of the proposed plants. All the calculations of the scenarios are based on the electricity consumption of 2015, for the reasons mentioned in Section 2.5. Table 2 shows the energy produced from each technology for all the examined scenarios, that can satisfy the need of 296,571 MWh.

Table 2
The energy policy scenarios.

Scenarios	Conventional fuel (MW h)	Wind energy (MW h)	Solar energy (MW h)	Natural gas (MW h)
Base case	248,757	32,934	14,880	–
Scenario 1	207,600	74,091	14,880	–
Scenario 2	148,285	133,406	14,880	–
Scenario 3	118,671	32,934	14,880	130,086
Scenario 4	77,514	74,091	14,880	130,086
Scenario 5	–	32,934	14,880	248,757
Scenario 6	–	74,091	14,880	207,600

5. Criteria

Wang et al.'s [28] literature review on the application of the MCDM techniques to the energy issues showed that evaluation criteria for alternative energy sources could be grouped into four main categories: technical, economic, environmental, and social. Strantzali and Aravossis [3] summarize the criteria utilized in energy planning studies up to year 2014. They showed that the most frequently used criteria are: efficiency, reliability, resource availability, investment cost, operation and maintenance cost, energy cost, payback period, CO_2 emissions, land use, job creation, social acceptability and social benefits.

In this study, the above mentioned most frequently used indicators are selected in evaluating the energy policy scenarios. The description of each criterion is as follows. The values obtained for each criterion are shown in Table 5. The values are selected through literature review, that their data comply with the proposed scenarios, and from international organizations (i.e. International Energy Agency).

5.1. Economic criteria

5.1.1. Levelised cost of electricity (LCOE)

There are several factors related to cost, that should be taken into consideration in order to accurately characterize the various technologies from an economic point of view [28]. The cost of generating electricity can be calculated in various ways. A widely accepted approach is the so called levelized cost of electricity (LCOE), or similar names such as average lifetime levelised generation cost (ALLGC), and levelised cost of generation (LCG) [29].

The aggregated cost indicator "Levelized Cost of Electricity" (€/kWh) has been used, because it allows to cover all the relevant financial aspects without overcomplicating the overall analysis.

$$LCOE = \frac{\sum_t (Investment_t + O\,\&\,M_t + Fuel_t)\bullet(1+r)^{-t}}{\sum_t (Electricity_t\bullet(1+r)^{-t})} \quad (4)$$

where $Investment_t$: Investment expenditure in year t

$O\,\&\,M_t$: Operation and Maintenance cost in year t
$Fuel_t$: Fuel expenditure in year t
$Electricity_t$: Electricity generation in year t
r: Discount rate

Table 3 shows the different costs for the three energy technologies.

For the analysis it was assumed: discount rate r=8%, and the examined time period t=20 years. The results from the calculation of the LCOE are in Table 5.

5.2. Technical criteria

5.2.1. Peak load response

Peak load response (points 0–5) (Table 5) is a qualitative indicator and reflects the technology's specific ability to respond swiftly to large temporal variations in demand. Base-load technologies, and those renewables which strongly depend on climatic conditions, are not suitable in this context and have very low score [33].

5.2.2. Efficiency

The efficiency indicator (Table 5) is calculated as a ratio, expressed as a percentage, of the output energy to the input energy. Efficiency is referred to how much useful energy (in this case electricity) it can be got from an energy source [34]. Plant efficiencies vary widely from as high as 95% for hydropower to the mid-range values (e.g., 35–45%) for gas and oil-fired turbines to 10–15% for geothermal [35].

5.2.3. Availability

The availability (Table 5) of a power plant is the amount of time that it is able to produce electricity over a certain period, divided by the amount of time in the same period. A power plant can be out of service due to maintenance or repairs and weather conditions such as the lack of sunlight or wind. Most steam-electric power plants, such as coal, geothermal, oil, natural gas, biomass and nuclear power plants, have availabilities between 80% and 96%. Photovoltaic, wind and hydro power plants have lower availabilities ranging between 20% and 50% [34].

5.3. Environmental criteria

5.3.1. Greenhouse gas emissions

Greenhouse gas emissions, shown in Table 5 as tons of CO_2 equivalent (tn $CO_{2\text{-eq}}$/MW h) were estimated according to the full operational life cycle of each energy technology including CO_2 emissions from manufacturing of the plant to full operation of the technology. The LCA emissions factors used in this study are based on the European Reference Life Cycle Database (ELCD). The ELCD provides Life Cycle Analysis (LCA) data for most of the fuels and, also, Member State specific electricity mix data [38].

5.4. Social criteria

5.4.1. Social acceptability

Social Acceptability (Table 5) refers to the opinions related to the energy systems of the local population regarding the hypothesized realization of the examined projects. It is extremely important since the opinions of the population and pressure groups may influence the amount of time needed to complete an energy project. Social acceptance is a qualitative indicator [10,36].

Table 4
The scale of the criterion "social impact".

Level of impact on local community	Value
Null impact on the local economy (none)	1
Feeble impact on the local economy (weak)	2
Mediocre impact on the local economy (only few permanent workplaces) (moderate)	3
Medium to high impact on the local economy (creation of new workplaces and development of a chain of enterprises in the energy production's sector)	4
Very high impact on the local economy (powerful impulse to the local growth, creation of small industrial regions in wide territorial areas)	5

5.4.2. Social impact

This criterion (Tables 4, 5) estimates the total social and economic contribution to the local development and welfare that may happen in the regions that house the energy projects. Likely results are: jobs creation, new chains of enterprises for energy supply, emerging enterprises, new industrial regions etc. [9].

5.5. Determination of weights

Weighting of criteria is carried out according to the hierarchical ranking of criteria, Simos approach [40]. The main advantages of the technique are: it is less arbitrary than direct assignment of weights, it is much simpler than most indirect techniques, it can be easily understood by decision makers and leaves them enough freedom to accurately articulate their preferences. The implementation of this technique presupposes the ranking of criteria in a decreasing order of preference. Indifference between criteria is expressed by placing them in the same rank, while spacing between criteria implies a higher weight to the upper ranked criterion. Table 6 gives an explanatory example of the way weights of importance are calculated from the defined rank order. The criteria C3, C5 are ranked with the highest weight, whereas the criterion C4 with the lowest. Criteria with the same rank are placed in the same row. The column "Number of criteria" indicates the number of criteria in each row, and the column "Weight" assigns a number to each criterion (in the blank rows the number is written in parenthesis). The rest of the columns are calculated according to the functions in the table. It should be noted that the selected technique could lead to a significant divergence in the weights of criteria, especially in cases where a large number of criteria is selected. It is necessary that decision makers are informed about the computational procedure followed in the model and are allowed to reconsider their judgment if they do not agree with the weights extracted from their initial ranking [9,41,42].

Weighting of criteria was carried out according to three different weighting strategies. Each strategy emphasizes different hierarchy of preferences. The preferences have been elicited from interviews with

Table 3
The costs in €/kW.

	Investment cost (€/kW)	**Yearly fixed O & M cost** (€/kW)	**Yearly variable O & M cost** (€/MW h)	**Fuel cost (€/tn) (*prices February 2016*[c, d])**
Oil[a]	–	18.4	9.6	302
Natural gas (LNG)[a]	1077 (replacement of old engines) 1500 (new plant)	12.6	6.4	287
Wind[b]	1360	34.6	–	–

[a] Source [30].
[b] Source IEA [15].
[c, d] Sources [31,32].

Table 5
The values for each criterion.

	LCOE (€/MW h)	Peak load response [33]	Efficiency (%)	Availability (%)	LCA emission factor (tn CO_{2-eq}/MW h) [38]	Social acceptability levels [39]	Social impact [9]
Oil	76.28	5	42 [30]	100[a]	0.31	Low	1
Natural Gas (LNG)	82.73 (replacement of old engines) 93.71 (new plant)	5	45 [30]	90[b] [37]	0.237	Medium	4
Wind	61.18 (new plant) 12.23 (existing plants)	0	100 [15]	38 [34]	0.007	High	4

[a] It is assumed that for the present it is totally available as the island is not interconnected and practically all the electricity demand is satisfied by the existing power plant.
[b] Because of the lack of infrastructure today.

Table 6
Criteria weighting (1st Strategy-example).

Ranking[a]	Criteria	Number of criteria (N)	Weight W	Average Weight $\overline{W}$=ΣW/N	Relative Weight (%) w = ($\overline{W}$/ΣW)×100
1	C4	1	1	1	**2.5%**
2			(2)		
3	C6, C7	2	3,4	3.5	**8.8%**
4			(5)		
5	C1, C2	2	6,7	6.5	**16.3%**
6			(8)		
7	C3, C5	2	9,10	9.5	**23.8%**
Total			**40**[b]		**100%**

[a] From the worst to the best criterion.
[b] Sum of the weights without the one in parenthesis.

stakeholders representing different occupational areas: academics, local authorities and potential investors. The above mentioned stakeholders were invited to participate in the planning process, though the interviews, as they can directly or indirectly influence the decision making process through their priorities in specific directions. This process resulted in three representative Strategies:

- 1st Strategy: A preference toward actions driving to a sustainable energy system for the island
- 2nd Strategy: A preference toward actions involving the highest economical and technical benefits
- 3rd Strategy*:* A preference toward actions generating the lowest environmental impact and the highest social benefits

In this way, it is possible to focus on three different strategy options, each one representing a coherent set of actions for different categories of decision makers. The percentage weight factors for the three strategies were estimated and presented in Table 7.

The criteria C3 (Peak load response) and C5 (Availability) have been classified with a high weight percentage in all three strategies as the electricity system of Lesvos is isolated and has fluctuations in the electricity demand. Based on the criteria selected to compare the alternative scenarios into the autonomous electricity grid of the island, Table 8 presents the evaluation matrix of the 7 energy policy alternative solutions (1st case).

For the determination of the values for the criteria C3-C7, it is calculated for each scenario, the contribution (in %) of each energy type in the total electricity demand. It is evident that none scenario excels the others in all criteria, imposing thus the application of multicriteria analysis. The results of this 1st case are shown in Table 14.

5.6. Sensitivity analysis in electricity demand

A sensitivity analysis has been carried out, considering the highest electricity demand in 2011 (307,864 MWh – Fig. 4) and the lowest electricity demand in 2014 (285,551 MWh – Fig. 4), to prove the robustness of the results. It is assumed that the energy produced from RES is not changing and the fluctuation of electricity demand are absorbed either by the existing power plant or the new natural gas power plant depending from the content of each scenario (Table 9). The results of the sensitivity analysis are shown in Table 15.

5.7. Sensitivity analysis in fuel price

Sensitivity analysis is, also, performed when conditions of uncertainty exist for one or more parameters. It was realized a sensitivity analysis using different prices of (LSHFO) and LNG. It is observed a high variation of the fuel prices during the last year. From March until July 2015 the price of LSHFO was around 540 €/mt, and had a downward trend after the summer reaching the price of 302 €/mt in the beginning of March 2016 [31]. At the same time, on April 2015, the LNG price for South Europe was around 8 €/mmBTU and had a downward trend, too [32]. Two more cases were examined, a second one with higher prices of LSHFO and LNG from the current prices and a third case with equal prices (Tables 10, 11). The evaluation matrices are in Tables 12, 13 and the results are shown in Table 14.

6. Results and discussion

The results obtained by the multicriteria evaluation are shown in Table 14. Figs. 5–7 show the calculated preference flows Φ for all the cases per strategy and Table 15 shows the results of the sensitivity analysis in electricity demand.

It becomes clear that the scenario SC5 significantly outranks all other scenarios from an overall point of view. Option “SC5” is prized

Table 7
Weights matrix for all strategies.

Criteria		Description	1st strategy	2nd strategy	3rd strategy
LCOE	**C1**	The total cost of generating electricity	16.30%	23.10%	3.90%
CO_2 emissions	**C2**	The CO2 emissions per unit of generated energy	16.30%	7.70%	21.10%
Peak load	**C3**	The technology's ability to respond to varying electricity demand	23.80%	23.10%	21.10%
Efficiency	**C4**	A ratio among the useful energy output and the energy input	2.50%	15.40%	3.90%
Availability	**C5**	The average time that the technology supplies electricity, including interruptions, planned or not.	23.80%	23.10%	21.10%
Social acceptance	**C6**	The opinions related to the examined technology	8.80%	3.80%	14.50%
Social impact	**C7**	The total social and economic contribution to the local development	8.80%	3.80%	14.50%

Table 8
Evaluation matrix for the 1st case.

Scenarios	Criteria						
	C1 (€)	C2 (tn CO_{2-eq})	C3 (qual.)	C4 (–)	C5 (–)	C6 (qual.)	C7 (qual.)
Base	19,377,235.64	77,345	4.42	0.49	0.93	0.12	0.47
SC1	18,756,044.40	64,875	3.68	0.57	0.84	0.26	1.05
SC2	17,860,820.79	46,902	2.63	0.69	0.71	0.47	1.89
SC3	20,216,813.67	67,849	4.42	0.50	0.88	0.35	2.31
SC4	19,595,622.42	55,378	3.68	0.59	0.79	0.49	2.90
SC5	23,714,888.10	59,186	4.42	0.51	0.84	0.56	4.00
SC6	22,376,016.61	49,720	3.68	0.59	0.76	0.63	4.00

Table 9
The policy scenarios for the sensitivity analysis in electricity demand.

Scenarios	High electricity demand				Low electricity demand			
	Conventional fuel (MW h)	Wind energy (MW h)	Solar energy (MW h)	Natural gas (MW h)	Conventional fuel (MW h)	Wind energy (MW h)	Solar energy (MW h)	Natural gas (MW h)
BASE	260,050	32,934	14,880	–	237,738	32,934	14,880	–
SC1	218,892	74,091	14,880	–	196,581	74,091	14,880	–
SC2	159,578	133,406	14,880	–	137,266	133,406	14,880	–
SC3	129,964	32,934	14,880	130,086	107,652	32,934	14,880	130,086
SC4	88,806	74,091	14,880	130,086	66,494	74,091	14,880	130,086
SC5	–	32,934	14,880	260,050	–	32,934	14,880	237,738
SC6	–	74,091	14,880	218,892	–	74,091	14,880	196,580

Table 10
Fuel price fluctuations.

	LSHFO price (€/mt)	LNG price (€/mt)
2nd case	540	429
3rd case	360	360

Table 11
The values of LCOE for the sensitivity analysis.

	LCOE (€/MW h)	
	Oil (LSHFO)	Natural gas (LNG)
2nd case	124.95	105.31 116.29 (new plant)
3rd case	88.22	94.34 105.33 (new plant)

above all others in all sustainability and environmental strategies. This is due in part to its cost being more contained, compared to its production capacity and consequently avoidance of HFO fuel, and in part to a modest overall environmental impact. Table 15 shows that the fluctuations in electricity demand do not affect the results. It is observed an inversion in some scenarios, that does not lead to a serious difference for the results obtained.

The fuel cost concluded to be a fundamental decision variable and had the most decisive contribution to the final ranking. In the economical and technical terms, the results differ: the 1st and 3rd cases are similar, whereas in the 2nd case is different. Scenario “BASE” comes out on top in economic and technical terms in the 1st and 3rd case. This happens because of the exceptional low price of oil marked the last year and forced us to examine the current alternative (1st case) and the alternative of equal LSHFO-LNG prices (3rd case). The fuel prices of the 2nd case are the most usual. Scenario “SC4” is categorized in the 1st position in this classification, followed by “SC5”. “SC4” includes the use of all types of the proposed solutions and has a moderate appearance in all the other classifications.

The next most suitable scenarios are SC3 and SC6. Both scenarios include natural gas: SC3 propose the partial replacement of the existing engines with new dual fuel engines and it could be said that it is a limited solution of the problem, SC6 refers to the partial contribution of wind energy in the energy produced from the new power plant. SC2 appears in the last positions. A greater penetration of wind energy seems to lead to a reduced reliance on conventional power plants. However, wind energy is not a stable source of energy that an autonomous electricity system can rely on. The alternative solution SC1 that introduce a low percentage of wind energy penetration is classified last in almost all alternative cases.

Table 12
Evaluation matrix for 2nd case.

2nd case	Criteria						
Scenarios	C1 (€)	C2 (tn CO_{2-eq})	C3 (qual.)	C4 (–)	C5 (–)	C6 (qual.)	C7 (qual.)
Base	31,484,729.29	77,345	4.42	0.49	0.93	0.12	0.47
SC1	28,860,309.56	64,875	3.68	0.57	0.84	0.26	1.05
SC2	25,078,153.05	46,902	2.63	0.69	0.71	0.47	1.89
SC3	28,929,753.72	67,849	4.42	0.50	0.88	0.35	2.31
SC4	26,305,333.98	55,378	3.68	0.59	0.79	0.49	2.90
SC5	29,331,134.20	59,186	4.42	0.51	0.84	0.56	4.00
SC6	27,063,034.54	49,720	3.68	0.59	0.76	0.63	4.00

Table 13
Evaluation matrix for 3rd case.

3rd case	Criteria						
Scenarios	**C1 (€)**	**C2 (tn $CO_{2\text{-eq}}$)**	**C3 (qual.)**	**C4 (–)**	**C5 (–)**	**C6 (qual.)**	**C7 (qual.)**
Base	22,346,998.24	77,345	4.42	0.49	0.93	0.12	0.47
SC1	21,234,449.06	64,875	3.68	0.57	0.84	0.26	1.05
SC2	19,631,109.84	46,902	2.63	0.69	0.71	0.47	1.89
SC3	23,144,004.79	67,849	4.42	0.50	0.88	0.35	2.31
SC4	22,031,455.61	55,378	3.68	0.59	0.79	0.49	2.90
SC5	26,603,243.23	59,186	4.42	0.51	0.84	0.56	4.00
SC6	24,786,482.97	49,720	3.68	0.59	0.76	0.63	4.00

Table 14
Results for all the cases.

Classification	1st strategy	2nd strategy	3rd strategy
1st case			
1	SC5	BASE	SC5
2	SC3	SC1	SC6
3	BASE	SC3	SC3
4	SC4	SC2	SC4
5	SC6	SC4	SC2
6	SC1	SC5	BASE
7	SC2	SC6	SC1
2nd case			
1	SC5	SC4	SC5
2	SC6	SC5	SC6
3	SC3	SC3	SC4
4	SC4	SC6	SC3
5	SC2	SC2	SC2
6	BASE	BASE	BASE
7	SC1	SC1	SC1
3rd case			
1	SC5	BASE	SC5
2	SC3	SC1	SC6
3	BASE	SC3	SC4
4	SC4	SC4	SC3
5	SC6	SC2	SC2
6	SC1	SC5	BASE
7	SC2	SC6	SC1

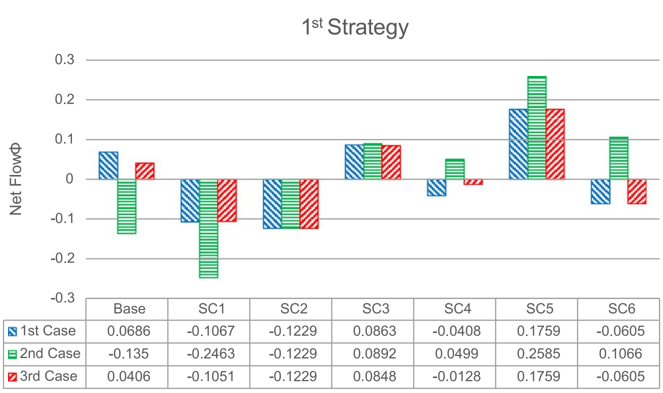

Fig. 5. The preference net flows Φ of the 1st strategy for all the cases.

Natural gas alternative (except the 2nd strategy) is always one of the best whatever the weights of the other criteria are decreased or increased. So, the results suggest that the ideal alternative includes the energy swift from conventional fuel to natural gas and the parallel penetration of wind energy.

7. Conclusions

Power generation problems belong to a set of critical domains where wrong management decisions may have disastrous economic, environmental and social consequences. In this paper, an attempt has been made to compare different energy production alternatives for a Greek island, Lesvos. In the case study of Lesvos 7 evaluation criteria, 3 possible decisional strategies, 3 different cases of fuel prices and 3 different electricity consumption alternatives, have been defined, in order to increase the flexible approach to the decision making. The performed sensitivity analyses aimed at investigating the ranking stability of the scenarios' hierarchy in relation to the most crucial model's coefficients which are the fuel cost and the fluctuations in electricity demand.

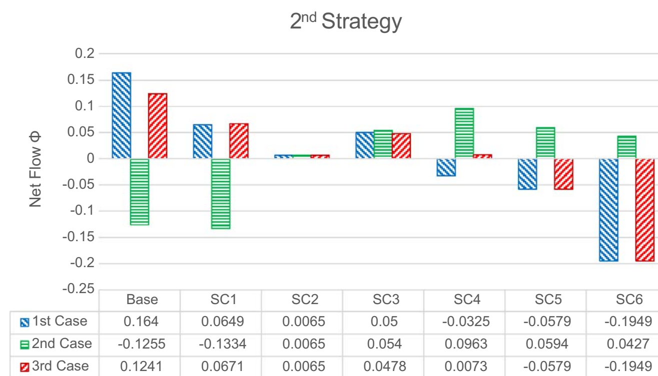

Fig. 6. The preference net flows Φ of the 2nd strategy for all the cases.

Fig. 7. The preference net flows Φ of the 3rd strategy for all the cases.

Results obtained by the multicriteria evaluation show that the alternative of natural gas and the combination of natural gas-wind are the most efficient solutions for the insular electricity system of the island. They dominate almost in all three strategies, "sustainable", "economic and technical" and "environmental/social". Scenario 1 is the least preferable scenario, whereas the "Base" scenario is at the bottom of the classification except the two "economical" strategies where the LSHFO price is significantly low. The results of the analysis show scenario SC5 to be the winner over the other hypothesized alternatives. The scenario SC5 emerges as the right compromise between costs, energy production capability, energy system stability and low environmental impact. Scenario SC2, although yielding the most economical

Table 15
Results of the sensitivity analysis in electricity demand.

	High electricity demand						Low electricity demand					
	1st strategy (Φ(SCn))		2nd strategy (Φ(SCn))		3rd strategy (Φ(SCn))		1st strategy (Φ(SCn))		2nd strategy (Φ(SCn))		3rd strategy (Φ(SCn))	
1	SC5	0.1688	BASE	0.1616	SC5	0.3606	SC5	0.1852	BASE	0.1535	SC5	0.3726
2	SC3	0.1103	SC3	0.074	SC6	0.1922	SC3	0.0962	SC1	0.0592	SC6	0.1924
3	BASE	0.0664	SC1	0.0553	SC3	0.0423	BASE	0.0618	SC3	0.0557	SC3	0.0306
4	SC4	−0.0404	SC2	−0.0005	SC4	0.0132	SC6	−0.0479	SC2	−0.0021	SC4	0.0083
5	SC6	−0.0528	SC4	−0.0366	SC2	−0.146	SC4	−0.0497	SC5	0.0399	SC2	−0.1387
6	SC1	−0.1197	SC5	−0.0674	BASE	−0.1803	SC1	−0.1166	SC4	−0.0498	BASE	−0.1848
7	SC2	−0.1327	SC6	−0.1864	SC1	−0.2818	SC2	−0.1292	SC6	−0.1765	SC1	−0.2804

energy production proposal with the lowest CO_2 emissions comes very far below the other options. This is because of the lack of stability and availability of wind energy, which makes it unsuitable to respond to peak loads of the island. The sensitivity analysis revealed that the parameter of fuel cost chosen could not affect the results of the sustainability and environmental cases (1st and 3rd strategy). The sensitivity analysis in electricity demand had slight, meaningless, effect in the obtained results.

This work demonstrates, also, that multicriteria analysis can provide a technical scientific decision making support tool, which is able to justify its choices clearly and consistently, especially in the energy sector.

This approach would be useful in view of the peculiarities of an island's electricity system, arising from the inability of interconnection with the mainland together with the imperative need of the reduction of the environmental impacts and the economical fuel costs in the future. Although the alternative scenario of an installation of a new power plant with dual fuel engines, is a capital-intensive investment, it seems to be the most attractive. The transportation of natural gas in its liquid form in the islands will contribute to the further penetration of natural gas in Greece, and in the same time, isolated systems will take advantage economically and environmentally. It should be highlighted that the habitants of those islands, although they are EU citizens, they do not have access to the alternative, environmental friendly, natural gas, which could be, also, utilized for domestic use in the future. Finally, a remarkable impact will occur to the local welfare, as local labor would be occupied in the construction of the LNG infrastructure.

Appendix A

Table A1 shows the preference flows for each criterion for all the scenarios. Different values among the three cases, are observed only for the criterion C1 (LCOE), as it depends on the fuel cost, which price is changing during the sensitivity analysis.

Table A2 shows the results regarding the preference flows (Φ) of the PROMETHEE II ranking, of the various strategies expressed numerically.

Table A1
The preference flows for each criterion separately.

Scenarios/Criteria	C1	C2	C3	C4	C5	C6	C7
1st case							
Base	0.2531	−1.0000	0.6667	−0.7500	0.9524	−1.0000	−1.0000
SC1	0.6238	−0.3860	−0.3333	0.2222	0.1905	−0.6667	−0.6667
SC2	1.0000	0.9413	−1.0000	1.0000	−0.9524	0.1667	−0.1667
SC3	−0.2905	−0.6140	0.6667	−0.6667	0.5714	−0.3333	−0.1667
SC4	0.0803	0.3126	−0.3333	0.3889	−0.3333	0.1667	0.3333
SC5	−1.0000	0.0207	0.6667	−0.5833	0.1905	0.8333	0.8333
SC6	−0.6667	0.7253	−0.3333	0.3889	−0.6190	0.8333	0.8333
2nd case							
Base	−1.0000	−1.0000	0.6667	−0.7500	0.9524	−1.0000	−1.0000
SC1	−0.2349	−0.3860	−0.3333	0.2222	0.1905	−0.6667	−0.6667
SC2	1.0000	0.9413	−1.0000	1.0000	−0.9524	0.1667	−0.1667
SC3	−0.2729	−0.6140	0.6667	−0.6667	0.5714	−0.3333	−0.1667
SC4	0.6380	0.3126	−0.3333	0.3889	−0.3333	0.1667	0.3333
SC5	−0.4922	0.0207	0.6667	−0.5833	0.1905	0.8333	0.8333
SC6	0.3620	0.7253	−0.3333	0.3889	−0.6190	0.8333	0.8333
3rd case							
Base	0.0806	−1.0000	0.6667	−0.7500	0.9524	−1.0000	−1.0000
SC1	0.6334	−0.3860	−0.3333	0.2222	0.1905	−0.6667	−0.6667
SC2	1.0000	0.9413	−1.0000	1.0000	−0.9524	0.1667	−0.1667
SC3	−0.3000	−0.6140	0.6667	−0.6667	0.5714	−0.3333	−0.1667
SC4	0.2528	0.3126	−0.3333	0.3889	−0.3333	0.1667	0.3333
SC5	−1.0000	0.0207	0.6667	−0.5833	0.1905	0.8333	0.8333
SC6	−0.6667	0.7253	−0.3333	0.3889	−0.6190	0.8333	0.8333

Table A2
The net preference flows Φ(X) for all the cases.

Classification	1st strategy		2nd strategy		3rd strategy	
1st case						
1	SC5	0.1759	BASE	0.164	SC5	0.3648
2	SC3	0.0863	SC1	0.0649	SC6	0.1827
3	BASE	0.0686	SC3	0.0500	SC3	0.0218
4	SC4	−0.0408	SC2	0.0065	SC4	0.0161
5	SC6	−0.0605	SC4	−0.0325	SC2	−0.1352
6	SC1	−0.1067	SC5	−0.0579	BASE	−0.1786
7	SC2	−0.1229	SC6	−0.1949	SC1	−0.2717
2nd case						
1	SC5	0.2585	SC4	0.0963	SC5	0.3846
2	SC6	0.1066	SC5	0.0594	SC6	0.2228
3	SC3	0.0892	SC3	0.054	SC4	0.0378
4	SC4	0.0499	SC6	0.0427	SC3	0.0225
5	SC2	−0.1229	SC2	0.0065	SC2	−0.1352
6	BASE	−0.135	BASE	−0.1255	BASE	−0.2274
7	SC1	−0.2463	SC1	−0.1334	SC1	−0.3051
3rd case						
1	SC5	0.1759	BASE	0.1241	SC5	0.3648
2	SC3	0.0848	SC1	0.0671	SC6	0.1827
3	BASE	0.0406	SC3	0.0478	SC4	0.0228
4	SC4	−0.0128	SC4	0.0073	SC3	0.0215
5	SC6	−0.0605	SC2	0.0065	SC2	−0.1352
6	SC1	−0.1051	SC5	−0.0579	BASE	−0.1853
7	SC2	−0.1229	SC6	−0.1949	SC1	−0.2713

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