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Multicriteria decision support in local energy planning: An evaluation of alternative scenarios for the Sustainable Energy Action Plan ☆

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ABSTRACT

One of the major challenges for the implementation of local energy planning is the successful development of a Sustainable Energy Action Plan (SEAP) by the local authorities (especially within the framework of their participation to the Covenant of Mayors' initiative). This aspect constitutes a decision making problem, since the local authorities have to identify the best fields of actions and opportunities for reaching their long-term CO_2 reduction target. However, the already available methods and tools do not offer an integrated framework for the SEAPs' development and especially the selection of sustainable Renewable Energy Sources (RES) and Rational Use of Energy (RUE) technologies. In this context, the aim of this paper is to present a participatory supportive framework for the implementation of local energy planning. At the first level, the proposed approach incorporates the development of alternative Scenarios of Actions (using knowledge-based process, participatory approach and aspiration level). At the second level, a direct and transparent multicriteria decision support is introduced, in order to evaluate the feasible Scenarios. It includes the application of a multicriteria ordinal regression approach and an extreme ranking analysis method for the estimation of the best and worst possible ranking position of each Scenario. The results from the pilot appraisal of the methodological approach to a "real" problem are presented and discussed. The adopted approach contributes to the selection of the most appropriate combination of RES/RUE actions, supporting in this way the local authorities to the development of their SEAP.

1. Introduction

The Covenant of Mayors is the mainstream European movement, involving local and regional authorities, voluntarily committing to increase Renewable Energy Sources (RES) and Rational Use of Energy (RUE) actions on their territory. The Covenant counts more than 6460 signatories so far.[1] The Sustainable Energy Action Plan (SEAP) is the key document in which the Covenant signatory outlines how it intends to reach its long-term CO_2 reduction target (at least 20% by 2020). The target sectors are the buildings, equipment, facilities and transport. The sustainable energy policy may also include actions related to the local electricity production (development of photovoltaics, wind power, combined heat and power, improvement of local power generation) and local heating/cooling generation [22].

In rural environments, fulfilling the Covenant's commitment of submitting a SEAP within a one-year timeframe can come with very challenging constraints. Some rural communities, and in particular those which are most remote, depopulated or dependent on agriculture, already face particular challenges as regards growth, jobs and sustainability [19]. These challenges include lower income levels, an unfavourable demographic situation, higher unemployment rates, a slower development of the tertiary sector, weaknesses in skills and human capital, a lack of opportunities for young people and a lack of necessary skills in parts of the agricultural sector and food processing industry [21,26]. This situation has been aggravated by the financial and economic crisis in the current years.

To the best of our knowledge, these areas do not possess adequate capacity to implement SEAPs and promote RES and RUE actions towards the development of sustainable energy communities. Climate change policies and programmes in these communities are still

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in their infancy, in terms of putting real changes on the ground [19]. Therefore, particular emphasis has to be also laid on them for "greening" rural communities economies [58].

The main objective of this paper is to present a participatory supportive framework for the implementation of local energy planning. At the first level, the proposed approach incorporates the development of alternative Scenarios of Actions, namely a set of RES and RUE actions for the local authorities, as well as interventions for the local population. This means that Scenario is a synonym of alternative. Following an initial design of alternatives through a knowledge-based process (modelling RES/RUE actions based on the selected criteria and using different ranges of application) and their finalisation through participatory approach, the filtering of feasible Scenarios for the local community is carried out using an aspiration level.

At the second level, a direct and transparent multicriteria decision support is introduced, in order to evaluate the feasible Scenarios. It includes the application of a multicriteria ordinal regression approach and an extreme ranking analysis method for the estimation of the best and worst possible ranking position of each Scenario. The results from the pilot appraisal of the methodological approach to a "real" problem (namely the development of a Greek municipality's SEAP) are presented and discussed.

Apart from the introduction, the paper is structured along five sections. Section 2 provides a description of the actual decision making problem and Section 3 is devoted on the relevant literature review. Section 4 is devoted to the decision process, including the relevant approach for the development of alternative Scenarios of Actions and the multicriteria decision support framework. Section 5 presents the results from the application of the adopted approach to the SEAP's elaboration and development of a Greek municipality. Finally, the last section just summarizes the key issues that have arisen in this paper.

2. Decision making problem

According to Marinakis et al. [61], the elaboration and development of a SEAP constitute a decision making problem. The local authorities have to identify the best fields of actions and opportunities for reaching their long-term CO_2 reduction target [22]. The selected measures and actions concern not only buildings and facilities that are managed by the municipality, but also other key areas of private sector, such as the residential and tertiary sector, public and private transportations, etc.

The key stakeholders of this decision making problem and their relationships are described below:

- *Decision Maker*: The local authority, namely the Mayor and Municipal Council, are responsible for the elaboration of the Action Plan, defining the overall goal of CO_2 emissions reduction by 2020 and the main priorities, in line with the vision defined.
- *Analyst*: The technical manager, in close collaboration with the local authority, contributes to the development of the baseline energy and CO_2 emissions inventory, as well as the identification of the appropriate mix of actions and measures that will be integrated in the Action Plan.
- *Third Parties:* The local stakeholders, who possess/control information, resources and expertise needed for strategy formulation and implementation, have active role in the planning process. The energy centers, investors, companies, representatives of the local market and citizens are potentially important stakeholders.

Building appropriate scenarios for the elaboration of SEAP, within the framework of the Covenant of Mayors initiative, is a complex task. In this respect, the methodological approach developed to address this decision making problem integrates standard techniques and methods, for the development of alternative Scenarios of Actions (participatory approach, aspiration level) and their evaluation (multicriteria analysis and robustness analysis).

3. Materials and methods

The materials and methods, which were used to address the decision making problem, are described below through an extensive literature review.

3.1. Participatory approach

- *Specifications:* All members of the society have a key role in establishing a common vision for the future and defining the paths that will make this vision come true [22]. According to Renn et al. [70], stakeholders, experts and citizens should contribute to the planning effort, through their particular expertise and experience. Indeed, their views should be integrated in the alternative Scenarios for the region. In this respect, the participatory approach can stimulate the behavioural changes that are needed to complement the SEAP's actions and measures.
- *Background Information:* The benefits of combining participatory methods with analytical tools are widely acknowledged [34,55,64,69,84]. Different ways to consider participatory approach have been identified, such as "Information", "Consultation", "Deciding together", "Acting together" and "Supporting independent community initiatives" [11]. In any case, the participation in planning could improve the quality, acceptance and effectiveness of the alternative action plans for the region [22].

3.2. Aspiration level

- *Specifications:* The local authorities set the minimum longer-term target in percentage of CO_2 emissions reduction. According to the Covenant's guidelines, the target should be a minimum of 20% reduction by 2020. However, the local authorities can define a different longer-term target. This means that the examined Scenarios for the region should achieve this longer-term target. To this end, an aspiration level regarding CO_2 emissions reduction of each alternative is used, working as a filtering for the identification of feasible scenarios.
- *Background Information:* A number of studies exist on the aspiration level approach [65]. More specifically, Wang and Zionts [91] examined the relationship between aspiration levels and their mapped-to solutions in the MCDA context. Yun et al. [93] presented an aspiration level approach using generalized data envelopment analysis and genetic algorithms in multiple criteria decision making such as engineering design problems. In the study of Granat and Makowski [36], the specified aspiration levels are used for the generation of component achievement functions for corresponding criteria, which reflect the degree of satisfaction of results.

3.3. Multicriteria decision support

- *Specifications:* Multiple Criteria Decision Aid (MCDA) methods can be an important supportive tool in policy making, providing the potential to evaluate the alternatives' implications to the

Table 1
MCDA in energy and environmental issues.

Method	Authors	Application area
Analytic Hierarchy Process (AHP)	Domenech et al. [14]	Electrification systems for rural communities
	Lanjewar et al. [56]	Assessment of alternative fuels for transportation
	Erol and Kilkis [24]	Energy source policy assessment
	Meyar and Vaez [63]	Energy policy making
	Awasthi and Chauhan [2]	Sustainable transport solutions
	Shen et al. [76]	Renewable energy sources
	Tegou et al. [85]	Environmental management
ELECTRE	Jun et al. [44]	Selection of wind/solar hybrid power station
	Rojas-Zerpa and Yusta [71]	Electric supply planning in rural remote areas
	Catalina et al. [7]	Multi-source energy systems
	Haurant et al. [40]	Photovoltaic plants
	Özkan et al. [66]	Solid waste management system
	Papadopoulos and Karagiannidis [68]	Decentralised energy systems
	Beccali et al. [3]	Decision-making in energy planning
Multi-Attribute Utility Theory (MAUT)	Volvačiovas et al., [88]	Public buildings retrofits strategy
	Kalbar et al. [49]	Wastewater treatment technology
	Kambezidis et al. [50]	Renewable energy sources
	Voropai and Ivanova [89]	Electric power system
	Pan et al. [67]	Strategic resource planning
PROMETHEE	Ghafghazi et al. [35]	District heating system
	Cavallaro [8]	Concentrated solar thermal technologies
	Terrados et al. [86]	Renewable energy planning
	Tsoutsos et al. [87]	Sustainable energy planning
TOPSIS	Aalami et al. [1]	Demand response programs
	Boran et al. [5]	Electricity generation
	Lee and Lin [57]	Energy performance of buildings
UTA	Sola and Mota [83]	Industrial motor systems
	Demesouka et al. [13]	Wastewater treatment
	Kholghi [54]	Wastewater planning management

environmental, economical and social axes [17,18,90,94]. In decision-making involving multiple criteria, the basic problem stated by analysts and decision-makers concerns the way that the final decision should be made [15]. The main idea of the available MCDA methods, is to create a more standardized and structured process for decision making [16,39].

- *Background Information:* In the international literature, there are studies that present applications of Multicriteria Analysis on specific issues related to sustainable energy planning (Table 1). In addition, a number of methodologies and tools have been developed for SEAP's elaboration, mainly within the framework of Intelligent Energy Europe (IEE) programme [4,58]. However, none of these studies offer an integrated framework for the SEAPs' development and especially the selection of the most appropriate sustainable RES and RUE technologies at local – regional level [59,60].

In the traditional aggregation paradigm, the criterion aggregation model is known a priori, while the global preference is unknown. On the contrary, the philosophy of disaggregation involves the inference of preference models from given global preferences [82]. The philosophy of preference disaggregation in multicriteria analysis is to assess/infer preference models from given preferential structures and to address decision-aiding activities through operational models. The existence of the preference model assumes the preferential independence of the criteria for the decision maker [53], while other conditions for additivity have been proposed by Fishburn [31,32]. This assumption does not pose significant problems in a posteriori analyses, such as disaggregation analyses.

In this context, an additive value model is proposed. A number of methods to obtain the proposed value system can be found in the literature [28,30,52], which requires explicit trade-offs between economic, political and social criteria. Taking into account the amount of cognitive effort needed, or for ethical reasons, their application in real world decision environments remains questionable. To this end, the analysts prefer to infer the additive value model from global preference structures, by applying disaggregation or ordinal regression methods. A survey of these methods and synergy of methods for the assessment of additive value models was recently presented by Hurson and Siskos [42], such as MACBETH technique, the standard MAUT trade-off analysis and UTA-based methods (UTA I, UTA II, UTAGMS, GRIP, RUTA, etc). UTA methods not only adopt the aggregation disaggregation principles, but they may also be considered as the main initiative and the most representative example of preference disaggregation theory [80]. The UTA II method was selected for the examined decision making problem, taking into consideration its main advantages, as follows:

- o Management of quality and quantitative criteria for the alternatives' evaluation.
- o Estimation of a set of additive value functions.
- o Integration of standard linear programming techniques.
- o The nature of the preferences, expressed as integrated weak order than through numeric values.

Over the past three decades UTA-based methods have been applied in several real-world decision-making problems (see [80] for a comprehensive survey on UTA methods and applications), with the most recent efforts focused on e-government and pharmaceutical strategic management [77,81]. Although, UTA method has been applied to a number of energy related problems (Table 1), there are not studies regarding sustainable energy planning at local/regional level.

3.4. Robustness analysis

- *Specifications:* The evaluation models of the multicriteria analysis are generally based on a set of acceptances, assumptions and estimations. These elements are often characterized by a high degree of uncertainty, given the complexity and uncertainty of the decision making environment [41]. In this respect, another important issue is the robustness of the evaluation model [72].
- *Background Information:* This fact has caused the intense interest of the research community. The recent studies focus on the development of integrated procedures for the robustness's analysis and measurement in different multicriteria analysis methods, as well as how these methods can adapt existing techniques to achieve the formation of stable solutions [33,62,78]. Some of the most recent UTA-type methods are UTA^GMS, GRIP, RUTA, extreme ranking analysis and robustness measurement control [29,37,38,45–48].

Table 2
Criteria evaluation scale.

	Index	Worst level	Best level
g_1	Quantitative (€)	120,000,000	0
g_2	Quantitative (€/kWh)	0.2	0
g_3	Qualitative	1	5
g_4	Quantitative (€/resident)	2000	0
g_5	Quantitative (%)	20	100
g_6	Qualitative	1	5

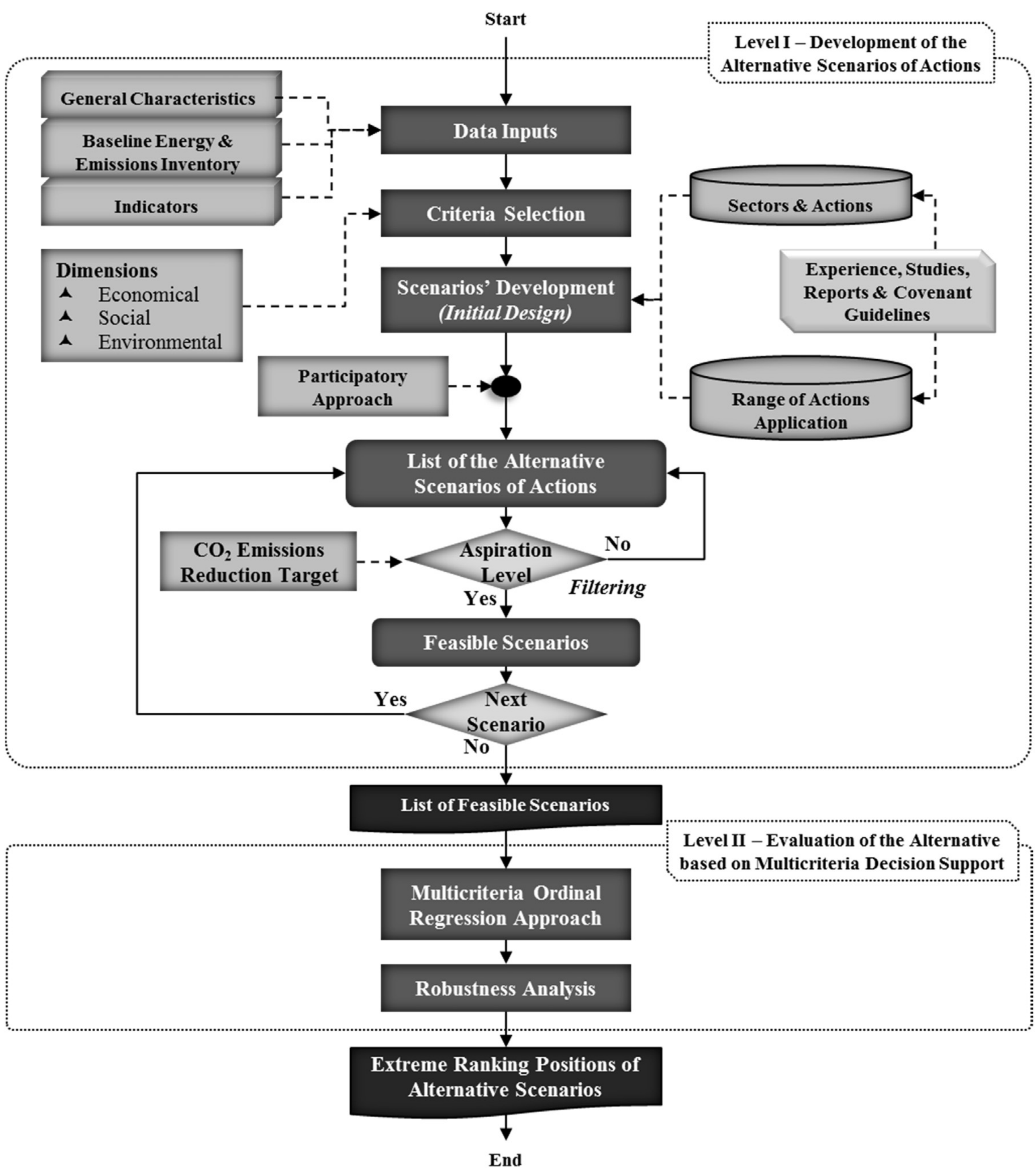

Fig. 1. Algorithm of the proposed approach.

Table 3
Sectors' and actions' identification.

Sector	Actions by the local authorities	Interventions by the local population
S_1 – Agricultural/Fishery/Forestry Sector	A_{11} Establishment/adjustment of a Department for Rural Development in the municipality. A_{12} Training seminars regarding the agricultural tractors' modernization and irrigation techniques. A_{13} Implementation of wide informational campaign. A_{14} Installation of an electronic water-supply system for irrigation based on debit cards.	I_{11} Modernization and replacement of tractors. I_{12} Replacement of surface irrigation and sprinkler irrigation with drip irrigation.
S_2 – Municipal Buildings, Equipment/Facilities	A_{21} Energy certification and improvement of the municipal buildings' energy performance. A_{22} Actions and campaigns for awareness raising of municipal employees. A_{23} Improvement of the school buildings' energy performance. A_{24} Actions and campaigns for awareness raising of pupils and students. A_{25} Energy Management System (in accordance with the ISO 50001). A_{26} Improvement of the sports facilities' energy performance. A_{27} Improvement of the energy performance of the water system and sewage treatment facilities. A_{28} Establishment of the Energy Efficiency Department in the Municipality. A_{29} Appointment of the municipality energy manager. A_{210} Remote configuration and control of the water system.	Not applicable
S_3 – Residential & Tertiary Sector	A_{31} Implementation of campaigns, events, energy days for the citizens. A_{32} Design and distribution of brochures about the benefits of interventions in the residential buildings. A_{33} Targeted seminars to professional groups. A_{34} Initiatives to support the citizens' actions. A_{35} Energy efficiency criteria for the purchase of electrical appliances	I_{31} Improvement of the building envelope (thermal insulation of walls, windows, roofs; external shading). I_{32} Retrofitting of residential buildings, bundling together technology improvements (lighting, electrical equipment, heat/cold systems, etc.). I_{33} Deployment of smart meters in households. I_{34} Installation of BEMs in commercial buildings.
S_4 – Public Lighting	A_{41} Gradual replacement of the existing bulbs in the public lighting with more efficient ones. A_{42} Dimmers depending on ambient conditions. A_{43} Installation of a public lighting management system. A_{44} Study of the municipal lighting.	Not applicable
S_5 – Industry	Not applicable	I_{51} Interventions by the relevant companies, including among others, replacement of boilers or installation of CHP for heating. I_{52} Ventilation with heat recovery. I_{53} Solar cooling for industrial processes. I_{54} BEMS.
S_6 – Municipal Fleet and Public Transport	A_{61} Eco-driving seminars for the drivers of the municipal fleet. A_{62} Replacement of the municipal vehicles with new, more efficient vehicles. A_{63} Converting diesel municipal vehicles to LPG. A_{64} Efficient management of the municipal fleet. A_{65} Municipal fleet maintenance.	Not applicable
S_7 – Private and Commercial Transport	A_{71} Eco-driving promotion in the private transportation. A_{72} Information events on the new vehicle technologies. A_{73} Cycle paths. A_{74} Traffic study. A_{75} Increase the use of public transport and alternative modes of transport. A_{76} Use of biofuels.	I_{71} Adoption of the eco-driving. I_{72} Use of LPG, hybrid, new technology vehicles. I_{73} Use of bikes and public transportation. I_{74} Use of the "car sharing" or "car pooling" concept.
S_8 – Local electricity production	A_{81} Installation of photovoltaic in the municipal buildings. A_{82} Installation of lighting points with photovoltaic panel. A_{83} Promotion of the installation of small PV parks in agricultural lands.	I_{81} Photovoltaics. I_{82} Wind farms. I_{83} Small dams and hydroelectric power plants. I_{84} Power plants using biomass. I_{85} CHP unites using natural gas.
S_9 – Local District Heating/Cooling	A_{91} CHP units using natural gas. A_{92} Heating/cooling production unit using biomass. A_{93} Development/enhancement of district heating network.	Not applicable

4. The methodological approach

4.1. Rationale

The proposed decision support methodology incorporates the following two levels (Fig. 1).

- *Level I – Development of the Alternative Scenarios of Actions*
  - o *Data Inputs:* Data inputs are used for the calculation of each criterion, such as general characteristics, baseline energy and CO_2 emission inventory, as well as indicators from the international literature and reports.
  - o *Criteria Selection:* Construction of a consistent family of criteria, based on the three (3) axes of preference, namely environmental, social and economical.
  - o *Scenarios' Development (Initial Design):* An initial design of the alternatives Scenarios take place through a knowledge-based process. First of all, a number of RES and RUE actions have been identified for the following sectors [10]: agricultural/fishery/forestry sector; municipal buildings, equipment/facilities (public, tertiary and residential); transport (municipal fleet, public transport, private and commercial transport); local electricity production (hydroelectric power, wind power, photovoltaic, combined heat and power, etc.); local district heating/cooling (combined heat and power, district heating plant, etc.). The Scenarios include different ranges of application of each action/measure in the relevant sectors, approaching the real needs and opportunities of each municipality, as possible.
  - o *List of the Alternative Scenarios of Actions:* The appropriate modifications are made on these Scenarios through a participatory approach (using questionnaires, public consultation meeting, etc).
  - o *Feasible Scenarios:* Following the finalisation of alternatives, the filtering of feasible Scenarios for the local community is carried out using an aspiration level (related to the CO_2 emissions reduction target).

- *Level II – Evaluation of the Alternative Scenarios based on Multicriteria Decision Support*
  - o *Multicriteria Ordinal Regression Approach:* The feasible Scenarios are evaluated through a direct and transparent additive value model, using an ordinal regression method.
  - o *Robustness Analysis:* The extreme ranking analysis method is used, in order to take into account the model's robustness, estimating the best and worst possible ranking position of each Scenario.

4.2. Level I – alternative scenarios of actions

4.2.1. Data inputs

First of all, a number of data are required by the end-user, as follows:

- *Baseline Energy & Emissions Inventory:* The baseline energy and emission inventory is developed, according to the Covenant's guidelines [10]. The inventory quantifies the amount of CO_2 emitted due to energy consumption in the territory of the Covenant signatory.
- *General Characteristics:* The end-user provides data regarding general characteristics of the municipality, as follows:
  - o *General Information:* population; area; climate zone; employment.
  - o *Agricultural Sector:* cultivate land; number of tractors; irrigation methods.
  - o *Municipal Sector:* number of municipal buildings; type and total area; number and type of pumps, drillings, water tanks, biological treatment
  - o *Residential Sector:* number of buildings and area; buildings with or without central heating; detached houses or block of apartments.
  - o *Tertiary Sector:* number of buildings, types and area
  - o *Municipal Lighting:* Number and type of lights
  - o *Transport*: Number of municipal cars, buses and other vehicles; number of private passenger vehicles, motorcycles, trucks, etc.
  - o *Locally Energy Production:* solar radiation; wind speed; river area and flow.

Except from the above-mentioned data, provided by the end-user, a number of indicators are also used from relevant studies and reports of the international literature [12,74,23,25,20,6,92].

4.2.2. Criteria selection

A number of criteria have been identified, according to the needs and opportunities of the sustainable development dimensions, namely the economic, social and environmental (Fig. 2). The selection of criteria is based on the proposed indicators by the CoM that could be used by the local authority to describe key actions highlighted as Benchmarks of Excellence [10]. Most of these criteria have been also applied to solve multicriteria problems in other related energy aspects, such as the formulation of sustainable technological energy priorities [15,18], identification of sustainable energy technology priorities for electricity generation under Clean Development Mechanism [51], ranking of renewable energy supply systems [75] and evaluation of thermal-energy storage [9].

The selected criteria satisfy the following requirements: monotony; exhaustiveness; cohesiveness; and non redundancy [73]. Under these requirements we ensure consistency of the family. Moreover, the selected criteria are preferentially independent, namely the trade-offs between the g_i and g_j criteria are not dependent on the values of the rest of the criteria [81].

More specifically, the necessary hypothesis to validate an additive value function for a given decision maker (DM) is the preferential independence of all criteria.

More specifically, the identified criteria are the following:

- g_1 *– Investment Cost for the Municipality (Quantitative Criterion – €):* Economic magnitude, expressing the cost for the implementation of RES/RUE actions by the local authorities. The cost may include actions in the municipal buildings, equipment/facilities, public lighting, municipal fleet and public transport, local energy production, as well as awareness raising activities in the agricultural, residential, tertiary sector and transport. The estimated investment cost for the municipality can be calculated by the following equation:

$$IC = \sum_{i=1}^{m} \sum_{k=1}^{l} IC_{A_{ik}} \tag{1}$$

where $IC_{A_{ik}}$ the investment due to the implementation of the action A_{ik} by the local authorities; i represent the number of sector and k the number of action within the relevant sector (S_1 – Agricultural/Fishery/Forestry Sector; S_2 – Municipal Buildings, Equipment/Facilities; S_3 – Residential & Tertiary Sector; S_4 – Public Lighting; S_5 – Industry; S_6 – Municipal Fleet and Public Transport; S_7 – Private and Commercial Transport; S_8 – Local electricity production and S_9 – Local District Heating/Cooling). All the actions A_{ik} are presented in Table 3.

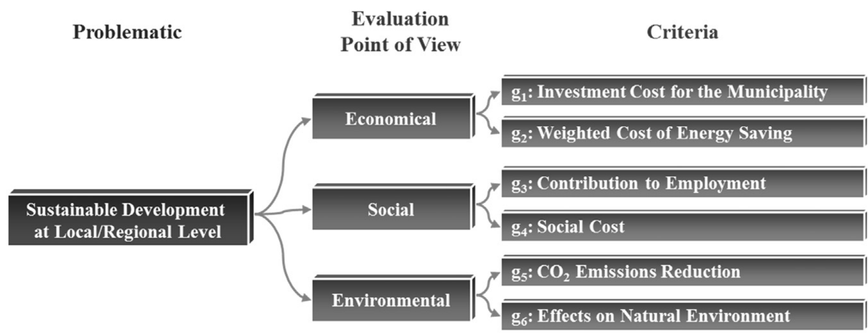

Fig. 2. The multicriteria evaluation system.

The higher the cost of the examined Scenario, the lower is its performance to this criterion.

- g_2 – *Weighted Average Cost of Energy Saving (Quantitative Criterion – €/kWh):* Evaluation of the potential profitability of the examined Scenario through the following equation.

The higher the social cost of the examined Scenario, the lower is its performance to this criterion.

- g_5 – *CO_2 Emissions Reduction (Quantitative Criterion – %):* Estimated reduction of the CO_2 emissions that will be achieved through the implementation of all the proposed RES and RUE

$$\text{Weighted Average Cost of Energy Saving} = \frac{\text{Initial Investment Cost } x\frac{ir}{1-(ir+1)^{-Duration}} + \text{Annual Maintenance Cost}}{\text{Annual Energy Saving}} \tag{2}$$

where *ir* is the interest rate.

It should be note that this criterion integrates the present value of the Scenarios' cash flow, ensuring in this way the independence property among criteria. It was selected since represents the minimum rate of return at which the authority produces value for its investors. The higher the value of the examined Scenario, the lower is its performance to this criterion.

- g_3 – *Contribution to Employment (Qualitative Criterion):* Reflects the impact of the examined Scenario in the social dimension regarding the creation of new jobs. The employment generated is often divided into two categories: investment (the most employment intensive part) and operation/maintenance (which last for the entire project's lifetime). It is a qualitative criterion and is derived as average value of the proposed actions in each Scenario. The performance of this criterion is assigned based on a 1-5 ordered qualitative scale, namely "1" very low (lower than 1%[2]), "2" low (higher than 1% and lower than 2%[2]), "3" moderate (higher than 2% and lower than 3%[2]), "4" high (higher than 3% and lower than 4%[2]) and "5" very high (higher than 4%[2]) contribution to employment regarding the particular Scenario.
- g_4 – *Social Cost (Quantitative Criterion – €/resident):* Reflects the total investment cost from the interventions of the local population (agricultural and residential sector, transport, etc). The estimated social cost can be calculated by the following equation:

$$IC = \sum_{i=1}^{m}\sum_{k=1}^{l} IC_{I_{ik}} \tag{3}$$

where $IC_{I_{ik}}$ the social cost due to the implementation of the intervention I_{ik} by the local population. i represent the number of sector and k the number of action within the relevant sector. All the actions I_{ik} are presented in Table 3.

[2] Increase of employment.

actions of each Scenario by 2020. The calculation of this criterion is based on the following data:

- o Development of the baseline emission inventory;
- o Estimation of the total CO_2 emissions reduction by 2020 using the calculations for the energy saving and production and related emissions factors.

$$CO2_{\%} = \frac{CO2_{base} - CO2_{reduction}}{CO2_{base}}$$

$$CO2_{base} = \sum_{i=1}^{m}\sum_{j=1}^{n} EC_{S_ij} x EF_j$$

$$CO2_{reduction} = \sum_{i=1}^{m}\sum_{j=1}^{n}\left(\sum_{k=1}^{l} ER_{A_{ik}j} x EF_i + \sum_{k=1}^{l} ER_{I_{ik}j} x EF_i\right) \tag{4}$$

where:

$CO2_{\%}$: Percentage of CO_2 emissions reduction due to the implementation of the Scenario (%)
$CO2_{base}$: Total CO_2 emissions in the baseline year ($tnCO_2$)
$CO2_{reduction}$: Total CO_2 emissions reduction due to the implementation of the Scenario ($tnCO_2$)
EC_{S_ij}: Consumption of the type of energy j in the sector S_i (MWh); for j=1: electricity, 2: heat/cold, 3: natural gas, 4: liquid gas, 5: heating oil, 6: diesel, 7: gasoline, 8: biomass, 9: solar thermal, 10: electricity, 11: other.
EF_j: Emission factor for the type of energy j ($tnCO_2$/MWh).
$ER_{A_{ik}j}$,$ER_{I_{ik}j}$: Energy reduction of the type of energy j due to the energy saving/production of the action A_{ik} and/or the intervention I_{ik}.

The higher the emissions reductions of the examined Scenario, the higher is its performance to this criterion.

- g_6 – *Effects on Natural Environment (Qualitative Criterion):* Reflects the Scenarios' interference level regarding the natural environment (e.g. visual intrusion, pressure on land resources and excessive land use). The performance of this criterion is assigned based on a 1-5 ordered qualitative scale, namely "1" very high, "2" high, "3" moderate, "4" low and "5" very low impact regarding the particular Scenario.

Following the criteria descriptions, the relevant evaluation scales are depicted in Table 2. It is noted that the worst and best level of quantitative criteria g_1 and g_4 are based on the knowledge gained from the already submitted SEAPs within the framework of the Covenant of Mayors.

4.2.3. *Scenarios' Development (Initial Design)*

The proposed approach includes the development of alternative Scenarios though a knowledge-based process. More specifically, based on desktop analysis (experience, studies, reports, best practices, etc.), different RES and RUE actions for the local authorities, as well as interventions for the local population have been identified (Table 3).

The implementation of all the proposed actions and interventions cannot be feasible at economical and organizational level, taking into consideration that each municipality has different characteristics in terms of population, infrastructures, construction of buildings, etc. In this respect, different ranges of application of each action/intervention in the relevant sectors have been selected for each alternative Scenario, approaching the real needs and opportunities of each municipality, as possible. This means that there are Scenarios with emphasis on the residential and/or tertiary sector, other Scenarios focus on actions from the local authorities (e.g. municipal buildings, equipment/facilities and public lighting), etc.

Indeed, the range of application of the proposed actions/interventions in each sector can be considered the value with the greater variability in its appreciation. The calculation of the energy consumption achieved from the implementation of each action/intervention is related to the number of residents, acres, buildings, etc. and the relevant energy consumption per unit (derived from the baseline emission inventory), the percentage of energy saving (based on the relevant indicators), as well as the range of application. The energy production from RES projects in the municipality depends on the installed capacity, efficiency and climatological data. The installed capacity, namely the range of application, is the main variable parameter. The investment cost and the social cost are also related to the number of residents, acres, buildings, etc. that the examined action concerns and the relevant unit cost (indicators from the literature or market research), as well as the range of application (expressed as a percentage of the number of consumers).

Fig. 3 depicts a qualitative representation of the range of application in each sector for the initial design of alternative Scenarios. The selection of the range was based on the experience from SEAPs' development and elaboration within the framework of the Covenant's initiative, as well as other related activities, such as the Intelligent Energy Europe (IEE) programme.

4.2.4. *List of the alternative scenarios of actions*

Following the initial design of alternatives, the participatory approach is used, so as to integrate the local stakeholders' views in the alternative Scenarios. To this end, a methodological 3-steps approach is proposed to identify and communicate with relevant stakeholders (Table 4):

- *1st Step – Identification:* Identify the stakeholders, namely those whose interests are affected by the issue or those whose activities affect the issue. The following checklist summarises the most important questions that are helpful for identifying stakeholders:
  - o Who possess/control information, resources and expertise needed for strategy formulation and implementation;
  - o Whose participation/involvement is needed for successful implementation.
- *2nd Step – Prioritisation:* Work out their power, influence and interest, in order to develop a good understanding of the most important initiatives and stakeholders, to know how they are likely to respond and to work out, how to win their support and to identify potential areas of collaboration or conflict amongst them;
- *3rd Step – Communication:* Plan how to communicate with interested stakeholders. Participation can be obtained through a variety of methods and techniques; different levels of participation and tools may be considered, as follows:

4.2.5. *Feasible scenarios*

Following the finalisation of alternatives, the filtering of feasible Scenarios for the local community is carried out using an aspiration level. The local authorities set the minimum longer-term target in percentage of CO_2 emissions reduction. According to the Covenant's guidelines the target should be a minimum 20% reduction by 2020. However, the local authorities can define a different longer-term target.

4.3. *Level II – multicriteria decision support*

4.3.1. *Multicriteria ordinal regression approach*

The proposed additive value model is described by the following form:

$$u(\mathbf{g}) = \sum_{i=1}^{n} p_i u_i(g_i) \tag{5}$$

subject to normalization constraints:

$$\sum_{i=1}^{n} p_i = 1$$
$$u_i(g_{i_*}) = 0, u_i(g_{i^*}) = 1, \forall i = 1, 2, \ldots, n \tag{6}$$

where $\mathbf{g} = (g_1, g_2, \ldots, g_n)$ is the performance vector of an alternative Scenario on the n criteria; g_{i_*} and g_{i^*} are the least and most preferable levels of the criterion g_i, respectively;$u_i, i = 1, 2, \ldots n$ are non-decreasing real valued functions, named marginal value functions, which are normalized between 0 and 1, and p_i is the relative weight of u_i.

Both the marginal and the global value functions have the monotonicity property of the true criterion. For instance, in the case of the global value function the following properties hold:

$$u[\mathbf{g}(a)] > u[\mathbf{g}(b)] \, if \, a \succ b(preference)$$
$$u[\mathbf{g}(a)] = u[\mathbf{g}(b)] \, if \, a \sim b(indifference) \tag{7}$$

A flexible and transparent approach is the UTA II method, proposed by Siskos [79], which has been used for the examined decision aiding problem. This method aims at inferring one or more additive value functions from a given ranking on a reference set of actions A_R [43]. It uses special linear programming techniques to assess these functions so that the ranking(s) obtained through these functions on A_R is as consistent as possible with the given one. UTA II method includes the following two phases:

- *Phase I: Construction of the marginal value functions* $u_i(g_i)$. The marginal value functions are built outside the UTA algorithm based on a questioning process [80]. The decision maker is asked to assign 3-4 value points $u_i(g_i)$ of the corresponding evaluation scale for each criterion separately [77]. Using appropriate options of Microsoft Office Excel, the regression line that

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Scenario	Agriculture	Municipal Sector	Residential Sector	Tertiary Sector	Public Lighting	Transport	Local Electricity Production	Local Heat/Cold Production
1	12%	50%	10%	10%	50%	12%	100%	100%
2	5%	20%	4%	4%	20%	5%	100%	100%
3	5%	5%	4%	4%	5%	5%	100%	100%
4	10%	5%	5%	5%	5%	10%	100%	100%
5	12%	50%	10%	10%	50%	12%	75%	100%
6	5%	20%	4%	4%	20%	5%	75%	100%
7	5%	5%	4%	4%	5%	5%	75%	100%
8	10%	5%	5%	5%	5%	10%	75%	100%
9	12%	50%	10%	10%	50%	12%	75%	75%
10	5%	20%	4%	4%	20%	5%	75%	75%
11	5%	5%	4%	4%	5%	5%	75%	75%
12	10%	5%	5%	5%	5%	10%	75%	75%
13	12%	50%	10%	10%	50%	12%	50%	75%
14	5%	20%	4%	4%	20%	5%	50%	75%
15	5%	5%	4%	4%	5%	5%	50%	75%
16	10%	5%	5%	5%	5%	10%	50%	75%
17	12%	50%	10%	10%	50%	12%	100%	0%
18	5%	20%	4%	4%	20%	5%	100%	0%
19	5%	5%	4%	4%	5%	5%	100%50%	0%
20	10%	5%	5%	5%	5%	10%	100%	0%
21	12%	50%	10%	10%	50%	12%	75%	0%
22	5%	20%	4%	4%	20%	5%	75%	0%
23	5%	5%	4%	4%	5%	5%	75%	0%
24	10%	5%	5%	5%	5%	10%	75%	0%
25	12%	50%	10%	10%	50%	12%	50%	0%
26	5%	20%	4%	4%	20%	5%	50%	0%
27	5%	5%	4%	4%	5%	5%	50%	0%
28	10%	5%	5%	5%	5%	10%	50%	0%
29	12%	50%	10%	10%	50%	12%	0%	0%
30	5%	20%	4%	4%	20%	5%	0%	0%
31	5%	5%	4%	4%	5%	5%	0%	0%
32	10%	5%	5%	5%	5%	10%	0%	0%

Fig. 3. Range of application for each alternative Scenario.

best fits the points is created (e.g. polynomial, etc.). In this way, each marginal value function is fitted and accepted by the decision maker.

- *Phase II: Estimation of the criteria weights p_i*

o *Selection of a reference set:* For the construction of the reference set by the analyst, virtual Scenarios are selected. The Scenarios of the reference set have to be known to the evaluators, in order to facilitate the decision maker in expressing

Table 4
Communication tools.

	Advantages	Disadvantages
Emailing, phone interviews	• It gives the opportunity to ask for the right person and explain everything and answer possible questions. • Very fast, the same e-mail can have several recipients.	• Many times no direct e-mail addresses are available
Face-to-face meetings, questionnaires, focus groups	• Very direct and effective • It gives the opportunity to get the attention of the right person/group and explain everything and answer possible questions	• Time consuming (needs preparation)
Consultation meetings, workshops	• Allows to attract several stakeholders at a time • Allows to involve stakeholders in a systematic and participatory manner	• Very time consuming • Requires a solid knowledge of potential stakeholders to be effective • High cost involved

the overall evaluation and representative of the whole set of alternatives [81]. The decision maker is asked to provide a ranking (weak order) of the virtual Scenarios. In each comparison, the two Scenarios are differed in two or at most three criteria values, so as to be possible by the decision maker to evaluate the Scenarios. As result, the Scenarios of the reference set $A_R = a_1, a_2, \ldots, a_m$ are rearranged in such a way that $a_i \succ a_{i+1}$ or $a_i \sim a_{i+1}$.

o *Linear programming techniques:* UTA II introduces two error σ^+ and σ^- on A_R by writing for each pair of consecutive actions in the ranking the analytic expressions:

$$\Delta(a_i, a_{i+1}) = \sum_{i=1}^{n} p_i \{u_i[g_i(a_i)] - u_i[g_i(a_{i+1})]\} - \sigma^+(a_i) + \sigma^-(a_i) + \sigma^+(a_{i+1}) - \sigma^-(a_{i+1}) \quad (8)$$

where:

$a_i \in A_R$ and $\sigma^+(a_i), \sigma^-(a_i)$ are the overestimation and the underestimation error respectively. These errors are not sufficient to minimize completely the dispersion of points all around the monotone curve of Fig. 4. The problem is posed by points situated on the right of the curve, from which it would be suitable to subtract an amount of value/utility and not increase the values/utilities of the others.

Then, the following linear program is solved:

$$\begin{aligned}
&[min]F = \sum_{i=1}^{m} \sigma^+(a_i) + \sigma^-(a_i)\\
&\text{subject to:}\\
&\Delta(a_i, a_{i+1}) \geq \delta, \text{ if } a_i \succ a_{i=1}\\
&\Delta(a_i, a_{i+1}) = 0, \text{ if } a_i \sim a_{i=1}\\
&\sum_{i=1}^{n} p_i = 1, \ p_i \geq 0, \sigma^+(a_i) \geq 0, \ \sigma^-(a_i) \geq 0 \quad \forall a_i \in A_R\\
&\text{with being a small positive number.}
\end{aligned} \quad (9)$$

It is noted that the solution of the above linear program may not be unique. In case of non-uniqueness, the algorithm finds the mean additive value function of those (near) optimal solutions which maximize the functions $u_i(g_i^*)$ on the polyhedron of the constraints of the linear program (9) bounded by the new constraint $\sum_{i=1}^{m} \sigma^+(a_i) + \sigma^-(a_i) \leq F^* + \varepsilon$, where F^* is the optimal value of the linear program (9) and ε a very small positive number. This means that the near optimal solutions corresponds to error values between F^* and $F^* + \varepsilon$. As a result, a representative sample of additive value functions may be obtained that is "close" to the optimal solution.

4.3.2. Robustness analysis

Analysis of the highest and the lowest ranks could significantly support the decision maker in the decision process. Among the most recent UTA-type methods (UTAGMS, GRIP, RUTA, extreme ranking analysis and robustness measurement control), the extreme ranking analysis of Kadzinski et al. [48] was selected, in order to identify multiple solutions. Through extreme ranking analysis, the relative performance of each alternative can be represented over the set of all instances of a preference model which are compatible with indirect preference information supplied by the decision maker.

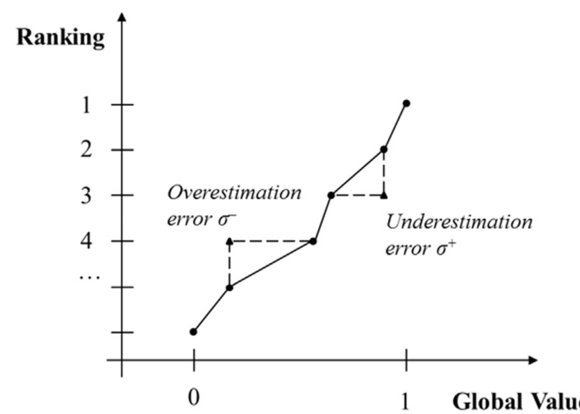

Fig. 4. Ordinal regression curve [80]

More specifically, the adopted approach evaluates the performance of each alternative relative to all other alternatives in a reference set A, determining the best and the worst ranks, and the score that an alternative can attain. This method is based on a general framework which can be applied irrespective of the type of the underlying model. In order to identify the highest rank of an alternative in the ranking provided by any compatible value function (or any compatible outranking mode) the following mixed integer linear program is calculated:

$$\begin{aligned}
&[min]F = \sum_{b \in A \setminus \{a\}} u_b\\
&\text{Subject to:}\\
&E_u^{A_R} \text{ Constraints}\\
&U(a) \geq U(b) - Mu_b\\
&\text{for all } b \in A \setminus \{a\}
\end{aligned} \quad (10)$$

where $E_u^{A_R}$ represents the constrains of the linear program (9) for the reference set A_R, U(a) and U(b) the global utility functions, M is an auxiliary variable equal to a big positive value and u_b is a new binary variable associated with comparison of Scenario a to alternative b.

In order to identify the lowest rank of an alternative in the ranking provided by any compatible value function (or any compatible outranking mode) the following mixed integer linear program is calculated:

$$[min]F = \sum_{b \in A \setminus \{a\}} u_b$$

$$\begin{aligned}&\text{Subject to}:\\&E_u^{A_R}\\&U(b) \geq U(a)+\varepsilon-Mu_b\\&\text{for all } b \in A\backslash\{a\}\end{aligned} \tag{11}$$

where $E_u^{A_R}$ represents the constrains of the linear program (9) for the reference set A_R, $U(a)$ and $U(b)$ the global utility functions, M is an auxiliary variable equal to a big positive value, ε is equal to a small positive value, and u_b is a new binary variable associated with comparison of Scenario a to alternative b.

5. Pilot appraisal

The proposed approach has been applied to the Municipality of Eurota, Greece, during the development of its SEAP for the Covenant of Mayors. The Municipality of Evrota has proceeded to the adoption of a series of initiatives and actions by 2020, taking into consideration that the local authorities' role is not limited to the provision of public services to citizens, but they ought to operate as a political, social and development body. The Mayor and municipal council of Evrota, exhibiting their strong political will and commitment towards sustainable energy planning, adhered to the Covenant of Mayors on the 24th April of 2012.

Table 5
Overview of the activities for the SEAP development.

Date of adhesion to the CoM initiative	24th April of 2012
Total number of stakeholders	364
Completed questionnaire	128
Date of the public consultation meeting	16th September of 2013
Number of participants to the meeting	41
Total participant to the unofficial meetings	36
Date of municipal council SEAP resolution	17th March of 2014
Date of SEAP submission to the CoM	17th March of 2014

5.1. Alternative scenarios of actions

5.1.1. Data inputs

The Municipality of Evrota is located in the southern part of the Prefecture of Laconia in Peloponnese. The Evrotas River is 82 km long, flowing in a north-south direction and emptying into the Laconian Gulf. The length of its coasts is 17 km and the population is 17,755 inhabitants. The Municipality is consisted of several villages and its headquarters is located in Skala which is 255 km from Athens. The municipality is in the climate zone A and the difference between average summer and winter temperatures is approximately 16 °C. As concerns land use, about half of the area is covered by forests and 44% by cultivated and fallow land. The municipality presents very high solar radiation (1200 KWh/KW$_p$). The total installed photovoltaic capacity was 1.300 KW$_p$ in 2010. On the other hand, it is not characterized by significant wind speed. As a result there is no wind park installation within the municipality.

Table 6
Criteria values.

Scenario	g_1 Investment Cost for the Municipality (€)	g_2 Weighted Average Cost of Energy Saving (€/kWh)	g_3 Contribution to Employment (1-5)	g_4 Social Cost (€/resident)	g_5 CO_2 Emissions Reduction (%)	g_6 Effects on Natural Environment (1-5)
1	49,075,394	0.11	5	1,126	29.25	1
2	35,491,990	0.12	5	511	20.31	1
3	25,317,284	0.13	4	511	19.96	1
4	26,344,570	0.13	4	891	27.16	1
5	48,862,640	0.12	5	1,005	25.78	1
6	35,093,203	0.12	4	456	17.90	1
7	24,438,001	0.13	4	456	17.59	1
8	25,567,553	0.13	4	795	23.93	1
9	39,785,110	0.10	5	994	25.49	2
10	26,319,902	0.11	4	451	17.70	2
11	16,342,534	0.12	3	451	17.20	2
12	17,797,385	0.12	4	786	23.67	2
13	37,444,810	0.10	4	917	23.46	2
14	24,375,819	0.12	4	416	16.29	2
15	14,887,169	0.13	3	416	16.01	2
16	15,762,341	0.13	4	725	21.78	2
17	70,91820	0.06	4	1,104	28.96	3
18	5,139,000	0.06	3	642	22.98	3
19	3,340,350	0.07	3	642	20.69	3
20	4,984,830	0.06	2	501	20.11	3
21	3,032,010	0.07	2	501	19.77	3
22	3,700,080	0.07	3	873	26.89	3
23	6,737,229	0.07	3	983	24.62	3
24	4,882,050	0.07	4	571	19.54	3
25	3,173,333	0.08	3	571	17.58	3
26	4,735,589	0.07	2	446	17.09	3
27	2,880,410	0.08	2	446	16.80	3
28	3,515,076	0.08	2	777	22.86	3
29	6,737,229	0.08	3	883	22.59	4
30	4,882,050	0.08	2	514	17.93	4
31	3,173,333	0.09	1	514	16.14	4
32	4,735,589	0.08	2	401	15.69	4
33	2,880,410	0.09	1	401	15.42	4
34	3,515,076	0.09	2	698	20.98	4
35	6,737,229	0.09	2	552	14.48	5
36	4,735,589	0.10	1	250	9.85	5
37	2,880,410	0.10	1	250	9.69	5
38	3,515,076	0.10	1	437	13.18	5

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The selected inventory year for the Municipality of Evrota is 2010. According to the energy and baseline emission inventory, the municipality consumed 275.6 GWh in 2010. The agricultural sector was responsible for 31.6%, the building sector and facilities for 36.3% and the transport sector for 32.1% of the total final energy consumption. The electricity consumption is estimated at 31.2%, heating oil at 13.2%, diesel 26.3%, gasoline 22.0%, biomass 6.4% and solar thermal 0.9% of the total final energy consumption. This energy consumption led to 140.6 ktn CO_2 emissions in 2010.

5.1.2. Participatory approach

For the municipality of Evrota, the decisive factor for the SEAP's successful implementation is the active contribution of all local stakeholders to the configuration of local energy and environmental policies. To this end, a number of unofficial meetings between the local key players (regional energy agencies, local chambers, producers of electricity and heat, citizens, members of the municipal council etc.) took place, as well as a public consultation meeting.

Moreover, a number of experts and stakeholders from the municipality of Evrota was identified, in order to properly analyse the needs and priorities of the community through the distribution of questionnaires. The different groups of stakeholders are the following:

- Representatives from the local and regional administration.
- Schools and citizens.
- Energy agencies, utilities and energy companies.

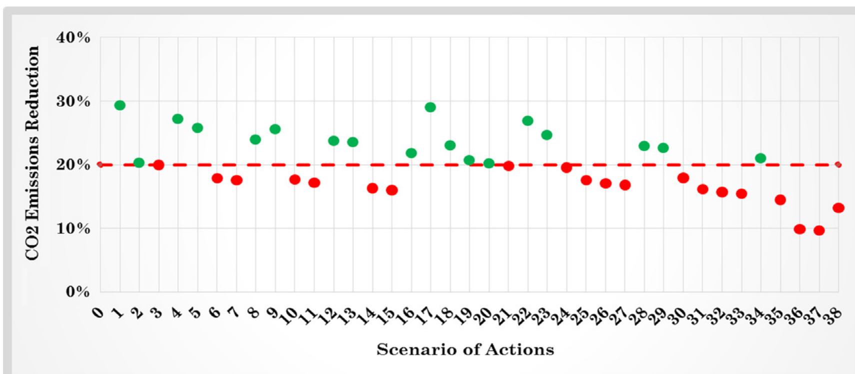

Fig. 5. Aspiration level – CO_2 emissions reduction 20%.

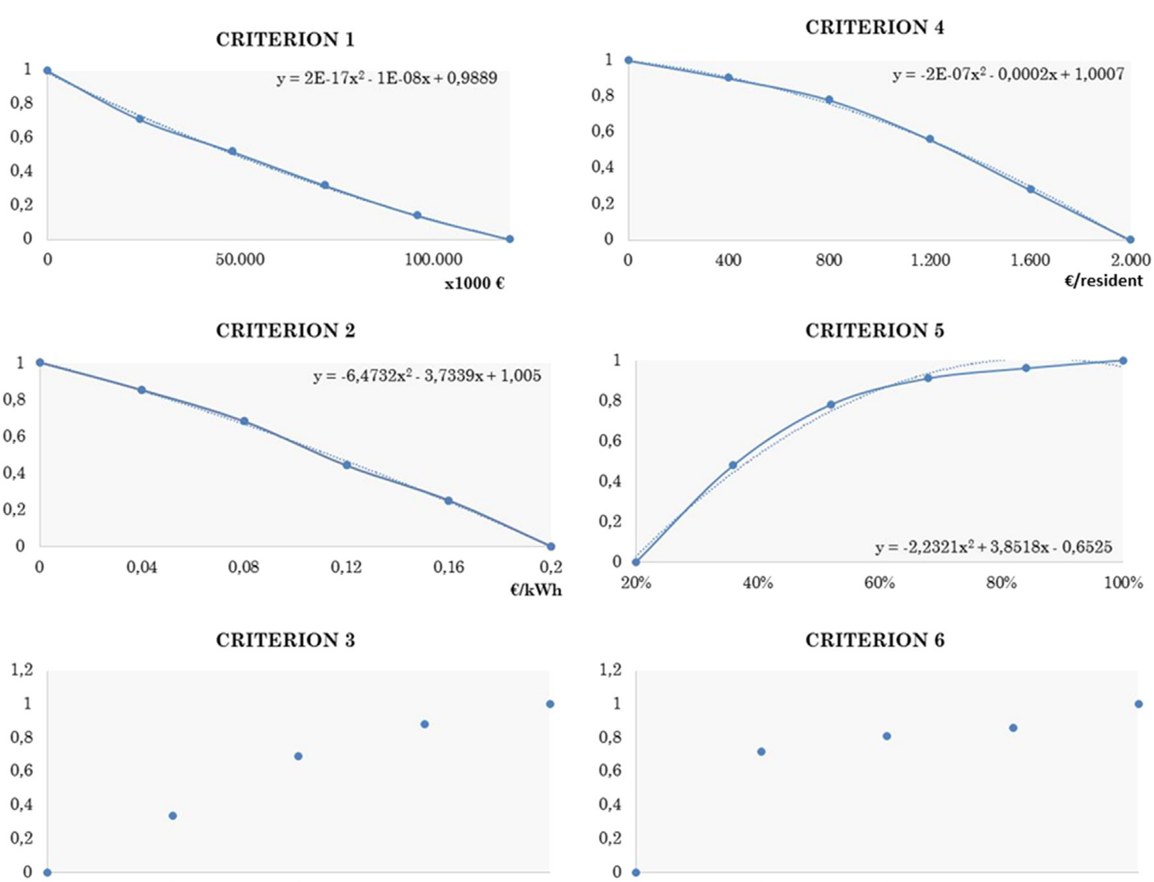

Fig. 6. Value function of each criterion.

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- Planners, developers.
- Farmers and agricultural producers.

The structure of the questionnaires and the overall approach regarding the engagement of the local stakeholders is based on the study of Marinakis et al. [58]. The state of work of the Municipality of Evrota concerning the SEAP development can be summarized as follows (Table 5):

Following the local stakeholders' feedback, six additional Scenarios were incorporated in the already developed alternative Scenarios, taking into consideration the low impact of the local energy production for heating/cooling in the region (Scenarios 1–16 in Fig. 3). It is noted that the municipality is located in the climate zone A with generally high temperatures during the year.

5.1.3. *Alternative and criteria values*

The criteria values of each alternative Scenario are presented in Table 6.

5.1.4. *Aspiration level (filtering)*

The selected level of the CO_2 emissions reduction target by the decision maker is 20%. Using this aspiration level, the Scenarios S3, S6, S7, S10, S11, S14, S15, S21, S24, S25, S26, S27, S30, S31, S32, S33, S35, S36, S37 and S38 are out from the evaluation process. These Scenarios are illustrated with red points in Fig. 5.

5.2. *Multicriteria decision support*

5.2.1. *Multicriteria ordinal regression approach*

The construction of the marginal value functions $u_i(g_i)$ is made by fitting a linear regression line (Fig. 6) to the collected value points by the decision maker (Table 7).

In addition, the reference set of Scenarios and the decision maker's ranking are presented in Table 8.

Based on the above, a linear program according to (9) is formulated, with $\delta = 0.001$. The linear program has multiple optimal solutions, since $[min]F = \sum_{a \in A_R} \sigma^+(a) + \sigma^-(a) = 0$. Thus, the mean additive value function of the near optimal solutions, which maximize the weights of each criterion, is calculated. The average of six solutions is calculated ($p_1 = 0.328569$, $p_2 = 0.170313$, $p_3 = 0.020639$, $p_4 = 0.190021$, $p_5 = 0.103029$, $p_6 = 0.187428$). This solution corresponds to the marginal value functions and produces a ranking (Table 9) which is consistent with the decision maker's initial weak order (Table 8).

5.2.2. *Robustness Analysis*

The solutions obtained during extreme ranking analysis are presented in Fig. 7. The grey colour represents the current ranking position, the brown colour the best possible ranking and the blue colour the worst possible ranking of each scenario. Scenarios "18", "20", "19" and "22" get a top ranking.

The differences between the extreme ranking positions of alternative Scenarios are either low (e.g. Scenarios «12», «16», «13», «19») or high (e.g. Scenarios «28», «17»). In general, the final ranking is not stable (average range of ranking positions 3.1). To this end, a reduction of the provided solution's variation is examined by modifying the constraints of the linear problem, so as to reduce the results' uncertainty. More specifically, the δ value changed to 0.01. In this context, the provided solution is $p_1 = 0{,}365424$, $p_2 = 0{,}165781$, $p_3 = 0{,}012161$, $p_4 = 0{,}209398$, $p_5 = 0{,}119501$, $p_6 = 0{,}127734$ and the initial ranking of the first four Scenarios «18» 0,764780, «20»

Table 9
Ranking – multicriteria ordinal regression approach.

Value	Scenario	Value	Scenario
0,770164	18	0,653890	12
0,764557	20	0,651084	16
0,762034	19	0,596230	13
0,760022	22	0,590137	9
0,743963	34	0,484087	8
0,742714	17	0,482334	4
0,742192	28	0,474292	2
0,737409	29	0,416024	1
0,732779	23	0,410541	5

Table 7
Value points of the decision maker.

Criteria values	g_1 Investment Cost for the Municipality (€)	g_2 Weighted Average Cost of Energy Saving (€/kWh)	g_3 Contribution to Employment (1-5)	g_4 Social Cost (€/resident)	g_5 CO_2 Emissions Reduction (%)	g_6 Effects on Natural Environment (1-5)
0%/1	0	0	0	0	0	0
20%/2	0,14	0,25	0,34	0,28	0,48	0,72
40%/3	0,32	0,44	0,69	0,56	0,78	0,81
60%/4	0,52	0,68	0,88	0,78	0,91	0,86
80%/5	0,71	0,85	1	0,9	0,96	1
100%	1	1		1	1	

Table 8
Reference scenarios and ranking of the decision maker.

Scenarios	g_1 Investment Cost for the Municipality (€)	g_2 Weighted Average Cost of Energy Saving (€/kWh)	g_3 Contribution to Employment (1-5)	g_4 Social Cost (€/resident)	g_5 CO_2 Emissions Reduction (%)	g_6 Effects on Natural Environment (1-5)	Preference Order	Global Value
A	5,000,000	0.06	3	600	20%	3	1	0.765
B	3,700,000	0.06	3	870	20%	3	2	0.748
C	3,700,000	0.09	3	870	25%	4	2	0.748
D	3,700,000	0.09	4	1,200	30%	4	4	0.733
E	15,000,000	0.09	4	600	20%	4	5	0.719
F	15,000,000	0.08	4	870	25%	4	5	0.719
G	25,000,000	0.08	5	870	25%	2	7	0.662

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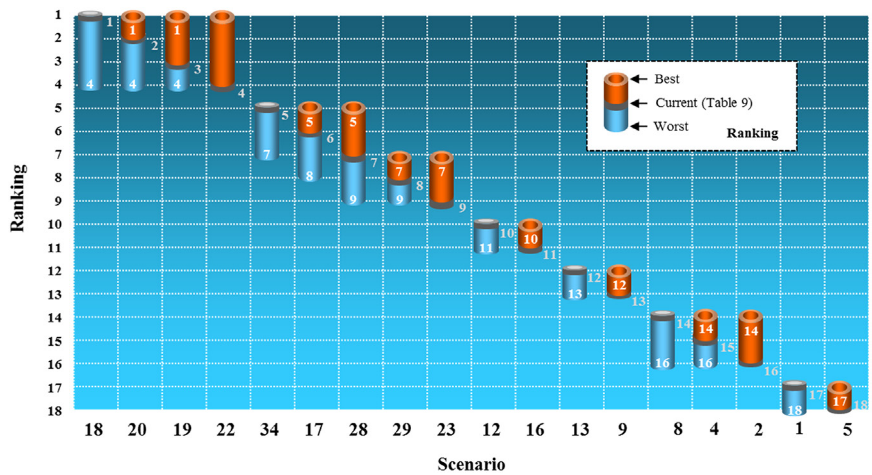

Fig. 7. Extreme ranking positions of alternative scenarios.

Table 10
Contribution of Scenario «18».

	Energy Saving/Production (MWh)	CO_2 Emissions Reduction (tn CO_2)	Costs (€)
Agricultural Sector	5.164	4.385	112.000
Municipal Buildings/ Equipment/Facilities	1.229	1.088	2.555.000
Public Lighting	726	821	720.000
Residential sector	5.279	4.491	61.000
Tertiary sector	1.791	1.378	17.000
Transport	6.936	2.256	1.353.000
Local Electivity Production	16.161	17.889	500.000
Total	37.286	32.308	5.319.000

Table 11
Profitability index.

	«18»	«20»	«19»	«22»
Profitability Index	1,89	1,29	1,62	1,30
Total Value ($\delta = 0.001$)	0,770164	0,764557	0,762034	0,760022
Extreme ranking positions	1-4	1-4	1-4	1-4
Total Value ($\delta = 0.01$)	0,764780	0,761816	0,756495	0,755298

0,761816, «19» 0,756495, «22» 0,755298. Following the robustness analysis, the new average range of ranking positions is 2.1 making the results more stable. However, the above four Scenarios («18», «20», «19» and «22») get also a top ranking.

As a result, the most preferable options are the above four Scenarios («18», «20», «19» and «22»). The local community selects the Scenario «18» for its SEAP, submitted on the 17th of March 2014 [27]. This means, that the overall CO_2 emission reduction target by 2020 is 23% and the overall estimated budget for the elaboration of the foreseen actions is 5,139,000 €. It includes a series of appropriate RES and RUE activities, laying balanced emphasis on the local electricity production (from photovoltaics) and the promotion and implementation of measures on energy savings (Table 10).

An additional step of the proposed approach for the selection of the appropriate Scenario among the four top ranked alternatives could be the calculation of profitability index. This index attempts to identify the relationship between the costs and benefits of the proposed Scenario of Actions. The profitability index is calculated by dividing the present value of the Scenario's future cash flows by the present value of investments. Based on the results, Scenario «18» seems to achieve the highest value among the four top ranked alternatives (Table 11).

6. Conclusions

Nowadays, sustainable energy policy has been a challenge for the local authorities. Indeed, the disengagement from the unilateral economic development may be achieved through the progressive dissemination of RES and RUE actions. As a result, the decision making problem of SEAP's elaboration and development within the framework of Covenant's initiative is an important component in local authorities' operation towards the creation of sustainable energy communities.

In this context, the proposed approach can support the local authorities to the:

- Development of the alternative Scenarios of Actions, namely a set of RES/RUE actions and interventions, taking into consideration the specific characteristics of the region. An initial design of alternative Scenarios took place according to a knowledge-based process. In this respect, a number of RES and RUE actions were identified for the agricultural, public, tertiary and residential sector, as well as transport and local energy production. Efforts were also focused on the adoption of rural communities' specific characteristics. Moreover, the adopted approach incorporated techniques of participatory approach and aspiration levels for the finalisation of the alternative and the filtering of feasible Scenarios for the region.
- Evaluation of the alternative Scenarios for the SEAP and selection of the most appropriate combination of actions. This paper provided a direct and transparent multicriteria evaluation model for local energy planning. An additive value model which is assessed by an ordinal regression method is adopted. Additional algorithms were incorporated using extreme ranking analysis, in order to identify multiple optimal solutions.

The results from the application of the adopted approach to the Municipality of Eurota, Greece, were used for the development of its SEAP for the Covenant of Mayors. It finally submitted on the 17th of March 2014. The creation of favorable conditions that will promote the area's energy performance and will attract new RES and RUE investments, is the core, on which the municipality's energy planning is based. It lays balanced emphasis on the local electricity production (from photovoltaics) and the promotion and implementation of measures on energy savings. The contribution

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towards addressing the climate change problem, through the municipality's CO_2 emissions' reduction and the creation of sustainable jobs, strengthening the extraverted economic activity at local level, comprise the success measure of this particular effort.

The potential replication of the proposed approach relies on the necessity for the local communities (rural, and not only) to create their SEAP. This stepwise approach, which guides the local authorities in the development of the alternative Scenarios for the region and their evaluation, is simple, concise and comprehensive. The proposed approach is not restricted only to rural communities, although their specific characteristics have been widely studied. On the contrary, it can be widely used by and support different types of communities and municipalities. Moreover, its general formation is strictly based on the Guidelines provided by the Covenant of Mayors, while it has been enhanced with additional aspects, as summarized below:

- Integration of the mulricriteria analysis and robustness analysis in the SEAPs' development, providing a comprehensive evaluation of alternative Scenarios; support to the decision making for the selection of the most appropriate sustainable RES and RUE technologies for the SEAP.
- A knowledge-based process for the initial design of alternative Scenarios in the region, taking into consideration its specific characteristics and main priorities (energy baseline, etc.).
- Integration of the local stakeholders' views on the formulation of alternative Scenarios for the region, raising the public awareness and making their citizens more self-conscious about the energy they consume and the new projects in the area.

Further issues for the extension of the previous research efforts are the development of the decision support system, based on the proposed approach, to provide step by step support to the decision makers. Different techniques could be incorporated to support the construction of the criteria value functions. More specifically, the construction of the value functions could be based on the use of functions with the general form $u = u(a, b, c; g_i)$. These general forms of functions are able to generate a satisfactory set of value functions of the criterion $g_i$for the different values of the parameters a, b and c. Moreover, visual procedures could be included, in order to provide a user-friendly environment.

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