DEVELOPMENT AND PRIORITIZATION OF RENEWABLE ENERGY SCENARIOS USING SWOT-FANP METHODOLOGY

by

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Original scientific paper
https://doi.org/10.2298/TSCI191018145S

The main goal of this paper is to develop and prioritize renewable energy scenarios for electricity production. The model proposed in the paper was applied on the example of the municipality of Štrpce, enclave in south Kosovo[**]. The model consists out of three phases, and the decision-making and planning process involves a group of decision makers, i.e. selected experts and stakeholders. In the first phase, a group of decision makers, using a collaborative planning method and Homer pro software, defined eight renewable energy scenarios based on renewable energy potentials and electricity demand in Štrpce. In the second phase, a group of decision makers, using the strengths, weaknesses, opportunities, and threats analysis, defined a total of 22 criteria to evaluate scenarios. Finally, in the third phase, a group of decision makers used fuzzy analytical network process methodology to prioritize scenarios. Results show that a scenario that includes installation of photovoltaic panels in Štrpce households to cover 50% of the electricity demand is first ranked. The proposed model has a universal character which means that it can be applied in other municipalities/cities and regions. Also, the model enables collaborative planning through the inclusion of different stakeholders whose number and type can be adjusted according to the subject/area of research.

Key words: *renewable energy sources, strengths weaknesses opportunities threat, homer pro software, energy security, electricity*

Introduction

A secure and uninterrupted supply of electricity is one of the preconditions for the development of every economy and society. The importance of energy has also been recognized by the UN, which declared the Decade 2014-2024 a *Decade of Sustain*able *Energy for All*, to ensure affordable, reliable and sustainable energy for all [1]. However, according to [2], as many as 1.1 billion people do not have access to electricity, although net electricity generation globally increased from 21.6 (trillion kWh) in 2012 to 25.8 (trillion kWh) in 2020 and is expected to see a rise up to 36.5 (trillion kWh) until 2040 [3]. Also, there are numerous problems in the energy sector of Kosovo[*] which endanger supply and they are summarized in [4]. Serbian communities

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[**] This designation is without prejudice to the status of Kosovo in accordance with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.

in Kosovo* are particularly vulnerable to unstable supply. One of them refer to municipality of Štrpce which is situated in the south of Kosovo*. The obsolescence of the distribution grid, frequent system failures, illegal grid connections, intentional exclusion, as well as the difficult terrain for maintenance makes electricity supply of Štrpce often unstable. An average annual electricity consumption in the Štrpce households is 11 MWh and 7 MWh in the apartments [5]. In the paper [6] nine strategies (strategic actions) for improving the energy security of Štrpce were defined. Utilization of locally available RES may be backbone for the long-term and complete solution of energy security issues. Therefore, the aim of this paper is to define and evaluate specific RES scenarios whose implementation can contribute to further improvement of the energy security of Štrpce. According to [7-9] RES potentials in Kosovo* are hydro energy (128 MW installed capacity, 621.816 GWh/year), wind (over 2000 GWh/year), solar energy (160 GWh/year), biomass (5908248 t/year).

According to [3] RES are the fastest growing sources of electricity generation with an average increase of 2.9% annually from 2012 to 2040, and according to [10] RES can be a long-term, sustainable and reliable support for implementation of energy policies/plans. However, a development and evaluation potential of RES projects is a complex endeavor that requires analysis of a number of factors, constraints, and stakeholders interests. Also, RES are already an indispensable part of strategic plans for energy development that are defined at a national and local level [4, 11]. For strategic planning purposes, strengths, weaknesses, opportunities, threat (SWOT) analysis is one of the most commonly used tool [10]. It provides an insight into the current situation of the research subject through identification of the SWOT that can be realized in order to develop RES plans and strategic goals [12, 13]. The SWOT analysis has been applied in the literature to solve various issues in the energy sector [14, 15]. However, conventional SWOT analysis cannot enable evaluation of SWOT factors and is therefore, often used in combination with multicriteria decision analysis (MCDA) methods such as analytical hierarchy/network process (AHP/ANP), preference ranking organization method for enrichment of evaluations (PROMETHEE), technique for order preference by similarity to an ideal solution (TOPSIS). The MCDA methods are used for different energy issues [16, 17]. According to [18] MCDA models allow stakeholders to participate in the process of comparing and evaluating alternatives, taking into account relevant criteria, thus creating conditions for collaborative planning and management as well as reducing stakeholder resilience in the implementation of RES plans. The problem that may arise relates to the possible inaccurate and intuitive evaluations of different participants in the decision-making process, which is why MCDA methods can be applied in a fuzzy environment [19, 20]. All of the aforementioned implies the need to develop a comprehensive SWOT-MCDA model for RES strategic planning that will enable the involvement of interested stakeholders.

Methodology

Planning and managing RES projects is a complex endeavor that has to include a number of factors (potentials, constraints, legislation, *etc.*) as well as many stakeholders who often have opposed interests that can lead to conflict situations. All of the previous points to the need of a systematic approach to RES planning and management. To this end, this paper proposes the application of collaborative planning aimed at maximizing stakeholder involvement and shared decision making [21]. Collaborative planning can contribute towards gaining more knowledge and generating more ideas as well as establishing better relationships with stakeholders [22]. Also, collaborative planning enables the creation of a common vision and goals

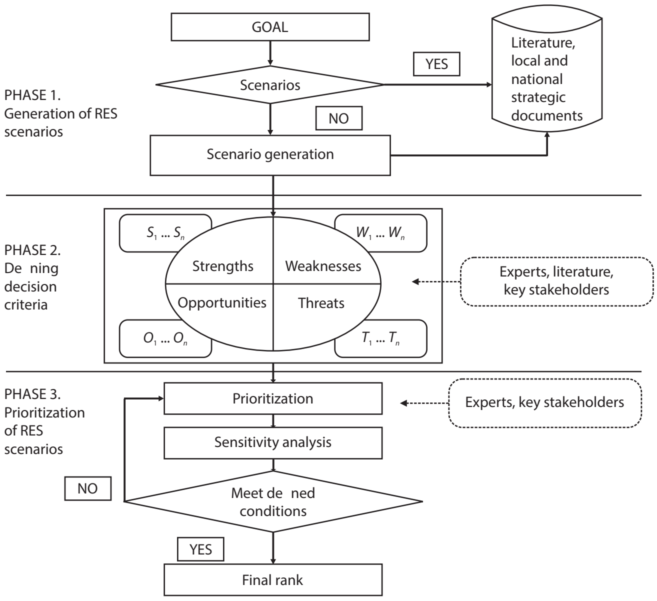

Figure 1. A model for generating and prioritizing RES scenarios

and is very important for launching joint actions [23, 24]. The aforementioned collaborative planning features can be used to define and implement RES scenarios that can lead to energy security improvements supported by the stakeholders.

Based on the literature analysis, a methodological framework has been defined to allow stakeholders to participate in the RES planning process. According to [25, 26] in order to achieve the defined goals, the development of scenarios and models is very important when making decisions about the energy system. Figure 1 presents an integral model for defining and prioritizing RES scenarios.

In order to involve stakeholders in the process of defining RES scenarios (Phase 1), an adapted three-step collaborative method was applied in section *Proposed and application*. After defining the scenarios, it is also necessary to define the appropriate criteria (Phase 2) that will be used to evaluate and rank the RES scenarios. Finally, the question of how to evaluate and select RES scenarios arises (Phase 3). Considering the multidimensionality of RES, the application of multicriteria decision-making methods is imposed as a logical choice. According to [27] there are no better or worse methods, but methods that fit better than others to solve a particular decision-making problem. For the purposes of this paper, ANP developed by Saaty [28] to address the weaknesses of AHP, is used. The ANP defines decision problem as a network whose elements can be connected in any way and allow to determine the interdependencies that exist between the elements. The ANP methodology consists out of the four basic steps [28-30]:

Step 1. Defining the model and structuring the problem. The decision problem must be precisely defined and presented in the form of a network.

Step 2. Comparison by pairs and determination of priority vectors. This step is similar to the AHP methodology. Elements of each cluster are compared and their priority compared to the control criterion is determined. Also, interdependence between criteria from different clusters is established.

Step 3. Formation of supermatrix. In order to obtain global priority in an interdependent system, local priority vectors are entered into the corresponding columns of the matrix. As a result, the supermatrix is actually a split matrix, where each segment represents a connection between the two clusters in the system.

Let the clusters in the system be marked C_k whereby $k = 1, 2,... n$, and each cluster k has m_k elements that can be labeled e_{k1}, e_{k2},..., $e_{km\mathrm{k}}$. The local priority vectors obtained in *Step 2* are grouped and placed in specific positions in the supermatrix based on a schedule in a unique eigenvector from one cluster to another C_k, and/or within the cluster itself, and/or within the loop.

Step 4. Selection of the best alternative. If the supermatrix formed in *Step 4* spans the entire network, the priority weights of the alternatives are in the alternative column of the normalized supermatrix. On the other hand, if a supermatrix only covers components that are interconnected, additional calculations must be made to get the overall priorities of the alternatives. An alternative with a high overall priority should be selected.

Stakeholders with insufficient knowledge of multi-criteria decision-making methods and RES are included in the research. Therefore, the assessment of the decision-making process can be intuitive and can depend on the human perception, which contains ambiguities and imprecision. In order to eliminate previous shortcomings fuzzy ANP (FANP) methodology was selected. Also, one of the advantages of the FANP method is that it allows the connections among different decision elements to be visible. In this sense, triangular fuzzy number (TFN) linguistic values can be used instead of the Saaty scale to form pairs of comparison matrices that represent decision elements. A more detailed overview of the use of fuzzy logic in the RES sector is given in the papers [31, 32].

Proposed model application

Phase 1. Generation of RES scenarios – for the generation of RES scenarios, an adapted collaborative planning method was applied in this paper. In the process of generating RES scenarios, an local energy expert and the same stakeholder clusters, which participated in strategic actions development in the paper [6] were included in the study: non-governmental organizations/NGO (6 NGO from Štrpce and five local companies), Kosovo* Electricity Distribution and Supply Company/KEDS (four local KEDS employees) and local governments (six representatives in total). Due to political circumstances, there are two local governments operating in Štrpce, one operating under the Kosovo* and the other under the Serbian legal system. Therefore, each local government participates with three representatives from different sectors. In this case, interested representatives of the local business sector are included within the NGO cluster. In the first step, a local energy expert presents to the stakeholders the goal of the research and then generates a set of initial RES scenarios using software (HOMER PRO). For the purpose of software modelling, data regarding electricity consumption in Štrpce and data regarding RES potentials are used. According to [33] average annual electricity consumption in Štrpce for the period 2014-2017 is 23.3 GWh with a maximum in January (2.5 GWh) and minimum in June (1.5 GWh). Potential of solar and wind energy in Štrpce was determined using HOMER PRO software, which retrieves data from the National Aeronautics and Space Administration (NASA) database. Hydro potential was determined based on the flow data from the Lepenac river based on the report [34]. The potential of biomass was determined by examining the available forest and agricultural areas in Štrpce by an expert (biomass expert). Based on the available data, an local energy expert using HOMER PRO software defined one initial scenario for each cluster. Then, within each stakeholder cluster, expert proposals were analyzed. By defining variations based on initial proposals submitted by an expert or proposing completely new solutions, each cluster defines a maximum of three new

RES scenarios. In cooperation with an expert and using HOMER PRO software, simulation is performed and the results are presented to the clusters. Each RES scenario was analyzed and modified within the clusters until a final list of scenarios was determined by consensus. In the third step, an open discussion was conducted among different clusters on defining the final list of RES scenarios that will present a further decision making subject. Analysis of selected scenarios show that different interests of all clusters are represented but also that each, to a greater or lesser extent, lead to the improvement of energy security. The scenarios are briefly described in the text that follows and basic data are given in the tab. 1.

Table 1. Basic data for generated scenarios (Source: HOMER PRO software)

	SCE_1	SCE_2	SCE_3	SCE_4	SCE_5	SCE_6	SCE_7	SCE_8
Investment/€ (1 house hold)	210745040 (74206)	20740520 (7303)	11292000	6661000	27024000	150613465	27401520	27024000
Energy price [€kW^{-1}h^{-}1]	1.24	0.097	0.411	0.083	0.074	0.6778	0.097 0.083	0.074
O&M costs [€]	74,887,960 (26369)	16,994,560 (5984)	3697528	403891	7126578	35428623	17398451	7126578
Energy sold [kWhyear^{-1}]	0	7432280 (2617)	0	2687738	12372	0	10120018	25821211
Annual production [kWhyear^{-1}]	89579280 (31542)	17625040 (6206)	6341053	5101502	25821211	69984512	22726542	25821211

Scenario 1 – The SCE_1 photovoltaic (PV) panels 25.4 kW, 17 kW converter, 120 kWh batteries, 78 hours autonomy – In order to cover complete household demand for electricity according to SCE_1, PV panels are planned to be installed. According to [5] there is a total number of 2840 households in Štrpce. With the implementation of SCE_1, every household in the territory of Štrpce would have complete autonomy in terms of electricity supply. The SCE_1 implies that PV panels to be installed on the roofs and/or on the household properties. This would avoid potential bureaucratic-political obstacles of Kosovo* institutions that could slow or even prevent the implementation of other RES projects. The disadvantage of the proposed scenario is the investment cost, tab. 1.

Scenario 2 – The SCE_2 (PV panels 5 kW, 2.63 kW converter) – The full autonomy proposed in SCE_1 requires large financial resources that households cannot provide on their own. That is why SCE_2 envisages the installation of PV panels to cover 50% of the required electricity while the rest is taken from the existing grid. In this way, households also enjoy a degree of autonomy, while a considerable part of (unused) electricity can be used to supply consumers in other regions.

Scenario 3 – The SCE_3 (1.2 MW hydro power plant, 1 MW biomass power plant, 1 MW solar PV power plant, 1 MW converter, 1 MW battery, 2 MWh batteries, 1000 new solar street bulbs; autonomy 3.89 hours) – RES is used for the complete (100%) supply of public consumers independently of the existing grid. Public consumers in this case include: institutions of pre-school, primary and secondary education; community health centre; telecommunications; cultural center and the police station. In this case, development of production facilities and distribution grid for the needs of the local public consumers is envisaged. Under this scenario, it is anticipated that citizens will be supplied with electricity using the services of the current supplier. For the purposes of street lighting, instead of the existing ones, it is planned to install new bulbs that will use solar energy. In this way, street lighting can be *removed* as a consumer of electricity from the existing distribution grid. At an annual level, the reduction of electricity consumption from the grid due to the change of street lighting amounts to about 50000 €.

Scenario 4 – The SCE_4 (1.2 MW hydro power plant, 1 MW wind power plant, 1 MW solar PV power plant, RES share 81.1%) – RES is used to supply 81.1% of the needs of public consumers (without street lighting) while the rest is taken from the existing grid. By doing so, the local population is supplied with electricity using the services provided by Kosovo* electricity supplier (KEDS). For the purposes of street lighting, as with SCE_3, it is envisaged to introduce new street lighting based on the use of solar energy.

Scenario 5 – The SCE_5 (16 MW wind turbines, 1.2 MW hydro power plant, 70.4% RES share) – RES is used to cover 70.4% of the total electricity demand while the rest is provided from the grid. In this case, a significant level of energy independence is achieved in relation the current supplier.

Scenario 6 – The SCE_6 (1.2 MW hydro power plant, 1 MW biomass power plant, 26 MW wind power plant, 23.6 MW solar PV power plant, 101 MWh batteries, 6.230 MW converter, 100% RES share) – Complete electricity requirements (100%) are provided using locally available RES. However, in this case particular attention should be paid to the stability and reliability of such a system, primarily due to the stochastic nature of RES. Also, the implementation of this scenario involves extremely high investment costs and complex bureaucratic procedures.

Scenario 7 – The SCE_7 (Combination of *Scenario 2 and 4*) - Lack of funding can be one of the major problems for the implementation of the aforementioned scenarios. That is why SCE_7, which is a combination of SCE_2 and SCE_4, is proposed as a transitional solution. The aforementioned scenario can be a good basis and a transitional solutionwards a continuous future increase of RES participation in order to cover the electricity demand.

Scenario 8 – The SCE_8 (16 MW wind power, 1.2 MW hydro power plant) – This is a variation of SCE_5 with the difference that the total amount of electricity produced is sold, thus contributing to the increase of the total electricity produced in Kosovo*, which will improve the overall energy security. The SCE_8 scenario provides investors with some financial gains from the sale of electricity. In KEDS is legally obliged to purchase the entire amount of electricity produced from RES (10 years for hydro power and biomass, 12 years for wind and PV energy). Also, incentive prices for electricity produced from RES were defined in the following amounts [4]: hydro power – 67.3 €/MWh, wind energy – 85 €/MWh, biomass – 71.3 €/MWh, PV – 136.4 €/MWh.

Phase 2. Defining decision criteria – Evaluating and selecting the right RES alternative is a complex task. In this regard, a number of criteria need to be analyzed. Various criteria and sub-criteria are used in literature for the evaluation and selection of RES. For the purpose of this research, with the help of literature, experts and stakeholders, applying the concept of SWOT analysis and through three steps, a list of criteria for evaluation of defined RES scenarios was generated. Also, certain criteria were obtained during generating RES scenarios in *Homer pro* software. In the process of defining the criteria, a group of decision makers (GDM) participated and is made up out of two experts (full professors in electrical engineering and RES with over 20 years' work experience in the planning and implementation of RES projects and grids) and three representatives of key stakeholders (local government, NGO and KEDS). In the first step, a global SWOT matrix was created, containing all the relevant criteria (45 criteria) identified by literature review, experts knowledge and key stakeholder surveys. In the second step, the GDM evaluates all the criteria of the global SWOT matrix using values (0-insignificant; 1-most important) with incremental increments of 0.1. In the third step, a final SWOT matrix is formed containing only the factors with an average weight coefficient ≥0.80. From the total of 45 criteria for the evaluation of scenarios, a total of 22 criteria were selected, tab. 2. Criteria are grouped into appropriate SWOT groups (strengths, weaknesses, opportunities, threats).

Phase 3. Prioritization of RES scenarios – After defining locally available RES scenarios (*Phase 1*) and then the criteria/sub-criteria of decision making (*Phase 2*), the prioritization of RES scenarios using FANP methodology can be performed (*Phase 3*). The GDM participated in prioritization (equally importance). Prioritization is implemented using Super decision software. The priorities assigned by the five decision makers have been fuzzified using TFN values. In the text that follows, the presented comparison matrices are a synthesized result of a GDM. By comparing SWOT groups, a matrix W_1 was obtained. The matrix of internal interdependence between the SWOT groups is presented through W_2.

Table 2. Final SWOT matrix/criteria

Strengths, *S*	Weaknesses, *W*
Autonomy level, S_1 Efficiency, S_2 Availability of resources, S_3 Ownership and management of local resources by the local community, S_4 Technology maturity, S_5	Non-constant RES production, W_1 High investment, W_2 High production cost of electricity, W_3 Negative impacts on quality of life, W_4 Significant land requirements, W_5
Opportunities, *O*	**Threats, *T***
Infrastructure development in the area of project implementation, O_1 Job creation, O_2 Using an existing distribution grid, O_3 Profit, O_4 Consistency with national and local RES policy, O_5 Increasingly cheaper and more affordable RES technologies, O_6	Unstable political situation, T_1 Social/political acceptability, T_2 Negative impacts by the Government of Kosovo*, T_3 Endangered water supply and irigation, T_4 Complicated and time-consuming licensing procedure, T_5 Low environmental awareness and knowledge about RES, T_6

$$\tilde{W}_1 = \begin{vmatrix} 0.250 & 0.346 & 0.420 \\ 0.250 & 0.200 & 0.221 \\ 0.250 & 0.271 & 0.223 \\ 0.250 & 0.183 & 0.135 \end{vmatrix} \quad \tilde{W}_2 = \begin{vmatrix} 1.000 & 1.000 & 1.000 & 0.333 & 0.349 & 0.426 & 0.333 & 0.484 & 0.571 & 0.333 & 0.388 & 0.490 \\ 0.333 & 0.316 & 0.388 & 1.000 & 1.000 & 1.000 & 0.333 & 0.287 & 0.286 & 0.333 & 0.316 & 0.312 \\ 0.333 & 0.349 & 0.300 & 0.333 & 0.278 & 0.326 & 1.000 & 1.000 & 1.000 & 0.333 & 0.296 & 0.198 \\ 0.333 & 0.335 & 0.311 & 0.333 & 0.373 & 0.249 & 0.333 & 0.230 & 0.143 & 1.000 & 1.000 & 1.000 \end{vmatrix}$$

In order to correct the fuzzy relative weights of the SWOT criteria, the fuzzy dependence matrix was calculated $\widetilde{W}_{\text{SWOTcriteria}} = \widetilde{W}_2 \times \widetilde{W}_1$.

$$\tilde{W}_{\text{SWOTcriteria}} = \begin{vmatrix} 0.250 & 0.309 & 0.354 \\ 0.250 & 0.223 & 0.245 \\ 0.250 & 0.251 & 0.224 \\ 0.250 & 0.218 & 0.177 \end{vmatrix}$$

Then, local fuzzy priorities of the SWOT criteria are determined and shown in the fuzzy matrices that follows (left). In addition the local, the global fuzzy priority of the SWOT criteria has been determined too, matrix $\widetilde{W}_3$.

$$\begin{array}{l} \tilde{W}_{\text{strengths}} = \begin{vmatrix} 0.164 & 0.195 & 0.262 \\ 0.195 & 0.195 & 0.199 \\ 0.252 & 0.258 & 0.270 \\ 0.194 & 0.172 & 0.139 \\ 0.195 & 0.180 & 0.130 \end{vmatrix} \\ \tilde{W}_{\text{weaknesses}} = \begin{vmatrix} 0.200 & 0.250 & 0.348 \\ 0.200 & 0.194 & 0.216 \\ 0.200 & 0.197 & 0.184 \\ 0.200 & 0.184 & 0.125 \\ 0.200 & 0.174 & 0.128 \end{vmatrix} \\ \tilde{W}_{\text{opportunities}} = \begin{vmatrix} 0.163 & 0.194 & 0.257 \\ 0.163 & 0.180 & 0.214 \\ 0.163 & 0.150 & 0.195 \\ 0.163 & 0.146 & 0.129 \\ 0.142 & 0.165 & 0.110 \\ 0.205 & 0.164 & 0.096 \end{vmatrix} \\ \tilde{W}_{\text{threats}} = \begin{vmatrix} 0.101 & 0.117 & 0.163 \\ 0.191 & 0.218 & 0.240 \\ 0.191 & 0.180 & 0.190 \\ 0.163 & 0.185 & 0.190 \\ 0.191 & 0.158 & 0.119 \\ 0.163 & 0.141 & 0.098 \end{vmatrix} \end{array} \cdot \tilde{W}_{\text{SWOTcriteria}} = \begin{vmatrix} 0.250 & 0.309 & 0.354 \\ 0.250 & 0.223 & 0.245 \\ 0.250 & 0.251 & 0.224 \\ 0.250 & 0.218 & 0.177 \end{vmatrix} = W_3 = \begin{vmatrix} 0.041 & 0.060 & 0.093 \\ 0.049 & 0.060 & 0.071 \\ 0.063 & 0.080 & 0.096 \\ 0.049 & 0.053 & 0.049 \\ 0.049 & 0.056 & 0.046 \\ 0.050 & 0.056 & 0.085 \\ 0.050 & 0.043 & 0.053 \\ 0.050 & 0.044 & 0.045 \\ 0.050 & 0.041 & 0.031 \\ 0.050 & 0.039 & 0.031 \\ 0.041 & 0.049 & 0.058 \\ 0.041 & 0.045 & 0.048 \\ 0.041 & 0.038 & 0.044 \\ 0.041 & 0.037 & 0.029 \\ 0.036 & 0.041 & 0.025 \\ 0.051 & 0.041 & 0.022 \\ 0.025 & 0.026 & 0.029 \\ 0.048 & 0.047 & 0.042 \\ 0.048 & 0.039 & 0.034 \\ 0.041 & 0.040 & 0.034 \\ 0.048 & 0.034 & 0.021 \\ 0.041 & 0.031 & 0.017 \end{vmatrix}$$

Further, the fuzzy relative importance of the RES scenarios was determined for each of the defined criteria and matrix $\widetilde{W}_4$ can be obtained in tab. 3.

Table 3. Elements of W~4 fuzzy matrix

	S1	S2	S3	S4	S5	W1	W2	W3	W4	W5	O1	O2	O3	O4	O5	O6	T1	T2	T3	T4	T5	T6
											B											
SEC 1	0.138	0.052	0.061	0.081	0.117	0.043	0.046	0.038	0.108	0.085	0.058	0.074	0.043	0.058	0.056	0.056	0.052	0.057	0.116	0.122	0.137	0.072
SCE 2	0.086	0.070	0.114	0.070	0.123	0.093	0.101	0.071	0.109	0.137	0.049	0.054	0.068	0.084	0.054	0.054	0.079	0.141	0.116	0.122	0.137	0.094
SCE 3	0.066	0.103	0.116	0.130	0.077	0.062	0.171	0.048	0.121	0.137	0.097	0.119	0.088	0.062	0.071	0.071	0.105	0.105	0.095	0.122	0.095	0.153
SCE 4	0.082	0.166	0.130	0.107	0.128	0.120	0.204	0.117	0.160	0.137	0.097	0.062	0.140	0.117	0.105	0.105	0.121	0.163	0.114	0.122	0.140	0.153
SCE 5	0.174	0.147	0.105	0.148	0.103	0.148	0.076	0.186	0.121	0.106	0.186	0.169	0.130	0.097	0.172	0.172	0.121	0.120	0.104	0.109	0.096	0.119
SCE 6	0.209	0.166	0.104	0.193	0.146	0.121	0.101	0.144	0.102	0.095	0.186	0.174	0.140	0.092	0.187	0.187	0.107	0.163	0.112	0.109	0.095	0.103
SCE7	0.142	0.104	0.162	0.162	0.149	0.155	0.171	0.138	0.166	0.165	0.115	0.153	0.140	0.204	0.142	0.142	0.116	0.131	0.164	0.172	0.165	0.103
SCE 8	0.102	0.191	0.209	0.108	0.157	0.258	0.131	0.257	0.114	0.140	0.213	0.194	0.250	0.285	0.213	0.213	0.300	0.120	0.180	0.122	0.137	0.203
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SCE 1	0.227	0.051	0.084	0.206	0.120	0.066	0.046	0.037	0.192	0.129	0.061	0.194	0.056	0.051	0.049	0.130	0.112	0.069	0.188	0.211	0.213	0.070
SCE 2	0.089	0.065	0.210	0.103	0.183	0.151	0.125	0.080	0.149	0.227	0.044	0.071	0.113	0.130	0.092	0.129	0.151	0.188	0.216	0.257	0.225	0.133
SCE 3	0.067	0.126	0.131	0.140	0.087	0.078	0.194	0.054	0.143	0.107	0.132	0.090	0.080	0.053	0.096	0.099	0.112	0.115	0.080	0.086	0.069	0.125
SCE 4	0.058	0.210	0.164	0.083	0.154	0.134	0.275	0.144	0.153	0.165	0.098	0.050	0.122	0.113	0.154	0.148	0.165	0.205	0.106	0.093	0.135	0.265
SCE 5	0.207	0.156	0.077	0.149	0.103	0.104	0.083	0.164	0.090	0.085	0.200	0.159	0.131	0.073	0.120	0.130	0.096	0.127	0.083	0.086	0.075	0.093
SCE 6	0.218	0.151	0.081	0.153	0.104	0.104	0.078	0.187	0.089	0.087	0.216	0.168	0.133	0.069	0.138	0.119	0.091	0.139	0.080	0.083	0.063	0.090
SCE 7	0.091	0.077	0.145	0.109	0.127	0.156	0.100	0.110	0.110	0.117	0.091	0.150	0.153	0.200	0.165	0.120	0.108	0.090	0.122	0.099	0.132	0.095
SCE 8	0.043	0.163	0.107	0.058	0.123	0.206	0.098	0.224	0.074	0.082	0.156	0.118	0.212	0.310	0.186	0.124	0.166	0.066	0.125	0.085	0.088	0.128
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SCE 1	0.279	0.076	0.168	0.340	0.229	0.120	0.115	0.040	0.296	0.267	0.072	0.331	0.119	0.059	0.086	0.274	0.252	0.177	0.274	0.280	0.284	0.197
SCE 2	0.149	0.094	0.252	0.173	0.235	0.230	0.155	0.130	0.215	0.242	0.048	0.098	0.199	0.171	0.231	0.234	0.256	0.224	0.299	0.291	0.269	0.216
SCE 3	0.089	0.173	0.133	0.150	0.090	0.097	0.197	0.049	0.142	0.103	0.222	0.133	0.125	0.047	0.142	0.123	0.096	0.139	0.091	0.088	0.066	0.135
SCE 4	0.075	0.247	0.143	0.086	0.143	0.168	0.231	0.167	0.140	0.150	0.152	0.041	0.144	0.124	0.184	0.116	0.172	0.171	0.103	0.091	0.136	0.194
SCE 5	0.210	0.140	0.100	0.075	0.103	0.099	0.073	0.179	0.051	0.064	0.206	0.122	0.112	0.072	0.108	0.086	0.064	0.122	0.065	0.066	0.068	0.071
SCE 6	0.124	0.107	0.055	0.091	0.066	0.066	0.072	0.177	0.070	0.074	0.134	0.122	0.092	0.055	0.099	0.064	0.051	0.087	0.046	0.063	0.038	0.066
SCE 7	0.050	0.064	0.099	0.057	0.069	0.130	0.090	0.092	0.053	0.065	0.073	0.081	0.105	0.206	0.095	0.069	0.049	0.046	0.076	0.075	0.089	0.060
SCE 8	0.024	0.098	0.050	0.028	0.064	0.089	0.067	0.166	0.033	0.035	0.093	0.071	0.104	0.266	0.056	0.033	0.057	0.035	0.046	0.048	0.050	0.062

The final priority of the RES scenario is determined by the matrix $\widetilde{W}_{\text{rang}}$. In the end, the final RES ranking is obtained by converting TFN to the exact values $\widetilde{W}_{\text{rang}}$.

$$\tilde{W}_{\text{rang}} = \begin{vmatrix} SCE_1 \\ SCE_2 \\ SCE_3 \\ SCE_4 \\ SCE_5 \\ SCE_6 \\ SCE_7 \\ SCE_8 \end{vmatrix} = \tilde{W}_4 \times \tilde{W}_3 = \begin{vmatrix} 0.076 & 0.116 & 0.188 \\ 0.094 & 0.141 & 0.190 \\ 0.101 & 0.104 & 0.124 \\ 0.129 & 0.143 & 0.145 \\ 0.132 & 0.121 & 0.115 \\ 0.138 & 0.124 & 0.088 \\ 0.150 & 0.121 & 0.082 \\ 0.184 & 0.131 & 0.071 \end{vmatrix} \Rightarrow W_{\text{rang}} \begin{vmatrix} SCE_1 \\ SCE_2 \\ SCE_3 \\ SCE_4 \\ SCE_5 \\ SCE_6 \\ SCE_7 \\ SCE_8 \end{vmatrix} = \begin{vmatrix} 0.127 \\ 0.142 \\ 0.110 \\ 0.139 \\ 0.122 \\ 0.116 \\ 0.118 \\ 0.128 \end{vmatrix}$$

The results of group decision making obtained by applying the FANP methodology are presented in the tab. 4. According to the results of group decision-making, SCE_2 (0.142) is first-ranked. In order to verify the reliability of the results obtained, a comparison of the rankings using the ANP and FANP methodology was performed using the Spirman coefficient, r_k, which is one of the important methods for determining the correlation between the results obtained by different approaches [35]. According to the result, the Spirman coefficient $r_k = 0.929$. For values of r_k greater than 0.8, the authors [35] find that there is a significantly high correlation, suggesting that the rank obtained is validated and relevant.

Table 4. Results of group decision making (ANP and FANP)

ANP			FANP		
Scenario	Average	Rank	Scenario	Average	Rank
SCE_2	0.155	1	SCE_2	0.142	1
SCE_4	0.147	2	SCE_4	0.139	2
SCE_5	0.132	3	SCE_8	0.128	3
SCE_8	0.128	4	SCE_1	0.127	4
SCE_1	0.120	5	SCE_5	0.122	5
SCE_7	0.114	6	SCE_7	0.118	6
SCE_6	0.103	7	SCE_6	0.116	7
SCE_3	0.097	8	SCE_3	0.11	8

Results and discussion

Based on the results of prioritization of RES scenarios presented in the previous chapter, a ranking list of RES scenarios can be presented, fig. 2. In order to improve energy security, the best results can be achieved through a combination of strategic actions and RES scenarios.

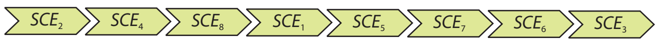

Figure 2. The RES scenarios rank (results of group decision making)

The SCE_2 (0.142) stands out as the top priority scenario based on group decision making. The SCE_2 implementation involves the installation of PV panels in households in order to cover 50% of electricity demand. By doing so, public and commercial/business customers continue to use the current service supplier. Unfortunately, given the poor financial situation, it cannot be expected for a large number of households to invest independently and fully in the installation of PV panels. Therefore, an appropriate form of financial support is needed that can be realized through the implementation of the strategic action SO_2 related to defining incentives at the local level for all stakeholders in order to use RES. Also, the results of the implementation of the strategic action WO_1 (raising awareness of the population on energy efficiency improvement and rational use of energy) can contribute to a more successful realization of SCE_2. By implementing only the SCE_2, energy security can be improved to some extent. However, in order to achieve a long-term, sustainable and substantial improvement of electricity supply, this paper proposes implementation of a series of scenarios SCE_2-SCE_4-SCE_8-SCE_1 (or SCE_6), respectively, which is also based on the results of group decision making. After SCE_2, it is proposed to implement the second-ranked scenario SCE_4, which covers electricity demand of the public consumers by 81.1% while the rest should be provided from the existing grid. Also, in SCE_4 it is necessary to replace the existing street lighting with new (solar) which will contribute to the increase of energy efficiency and savings in the local government budget. The implementation of the WT_1 strategic action (introducing energy management in the public, commercial and industrial sectors and establishing a municipal energy office) will create favorable conditions for the implementation of SCE_4, which is reflected in a more rational use of energy by the public consumers, leading to a reduction in consumption and, consequently, a reduction in the required RES production capacity to meet the demand. However, the implementation of SCE_4 requires significant financial resources, obtaining various permits and involving a number of stakeholders in the planning and implementation process. All of the aforementioned points to the need for a specific legal investment model. In this regard, the energy co-operative (EC), which is the result of the strategic action of ST_2 (defining the appropriate investment and legal model to build RES capacities) can assume the role of planning, managing and implementing RES projects. Following successful implementation of the SCE_4 scenario, the EC is expected to continue to further develop and increase RES capacity, thus leading to a further improvement of Štrpce energy security. After SCE_4, the implementation of the third-ranked scenario SCE_8 (0.128) is proposed. The implementation of SCE_8 implies the development of significant RES capacity (18.2 MW) which also requires significant financial resources (27024000 €). Part of the required funds can be provided by EC members, because the previous scenario implies that all electricity is sold at preferential tariffs for a certain guaranteed period of time (up to 12 years). In this way, EC members can expect a return on their investment as well as some financial gains from the sale of electricity. In order to raise the missing funding, a strategic action SO_3 (establishment of working group for co-operation with international institutions in order to provide political support and funding for renewable energy projects) can be implemented. Also, during the guaranteed purchase of electricity produced from RES at preferential prices, it is necessary to accumulate as much financial resources as possible. In addition the profits from the sale, assistance should be provided in the form of donations from local governments, central level institutions, and domestic and foreign donors. After 10-12 years, it is necessary to analyze the circumstances and determine whether there are financial and legal preconditions for the implementation of the SCE_1 scenario, the implementation which would lead to complete energy independence of all consumers/households in the territory of Štrpce. However, despite the steady decline in costs in the field of solar energy and energy storage, the realization of SCE_1 is expected to be financially difficult in the next 10-12 years. Therefore, in order to achieve complete energy independence in addition SCE_1, the implementation of the SCE_6 scenario, which requires significantly less financial investment, should be considered too. In this case, it is necessary to determine whether RES potentials are sufficient to cover all electricity demand and whether there are financial and legal preconditions for its realization. If the aforementioned conditions are fulfilled, then the strategic action WT_2 (construction of a new local grid for the RES island operation) should be implemented. Developing sufficient RES capacity for electricity generation and distribution grid would achieve complete energy security/independence from the current supplier. However, if any of the conditions for the implementation of SCE_1 or SCE_6 are not met, further development of SCE_8 should be considered by increasing the originally defined capacities in accordance with legal and financial capacity. The increase in the price of electricity in Kosovo* and Serbia, which is expected in the coming period, will enable the EC to continue to operate profitably after the end of the preferential price period, while contributing to the improvement of local and regional energy security. Figure 3 presents an aggregated plan for implementation and management of the generated RES scenarios.

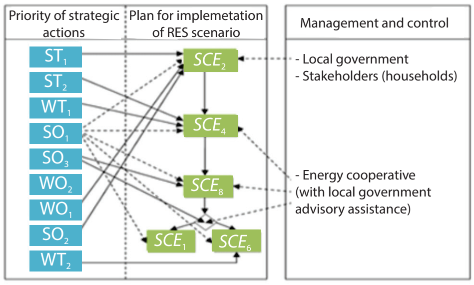

Figure 3. Implementation and management plan

Conclusion

The characteristics of the modern society, such as an increase in population, urbanization and industrialization require a redefinition of the strategic decisions in order to meet the increased energy needs, and in this sense, renewable energy can be a long-term, sustainable and reliable support to the implementation of energy policies/plans [10]. In this paper SWOT-FANP method is used to define and rank eight RES scenarios suitable for municipality of Štrpce. One of the main problems in the realization of the RES projects relate to the resistance of the stakeholders. Therefore, this paper proposes a model that enables the involvement of all interested stakeholders in the process of planning and managing RES projects. In this way, it is expected to make relevant decisions and reduce resistance and conflicts with stakeholders, which lead to better results and better sustainability of RES projects. The proposed model consists out of three phases with universal character, thus it can be applied in other regions/countries and for different research subjects. According to the results of group decision-making, SCE_2 is the first ranked scenario, which can partly contribute to the improvement of energy security. However, for the purpose of a long-term, comprehensive and sustainable improvement, this paper proposes implementation of a series of RES scenarios SCE_2-SCE_4-SCE_8-SCE_1 (or SCE_6), which is also based on the results of group decision-making. For the purpose of future research, RES scenarios need to be elaborated and analyzed in detail.

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Paper submitted: October 18, 2019
Paper revised: March 2, 2020
Paper accepted: March 20, 2020