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An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey's energy planning

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ABSTRACT

Energy planning involves a perpetual process of reevaluating alternative energy strategies. Authorities responsible for energy planning and management have to adjust their strategies according to new and improved alternative solutions based on the sustainability criteria. In this study, we propose an integrated hybrid methodology for the analysis of Turkey's energy sector using Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, Analytic Network Process (ANP) process, and weighted fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) to formulate and holistically analyze the energy strategy alternatives and priorities. The methodology proposed in this study allowed identifying the relevant criteria and sub-criteria using a SWOT analysis. Then, ANP approach, which is one of the popular multi-criteria decision making (MCDM) methods, is employed to determine the weights of each SWOT factors and sub-factors. Finally, fuzzy TOPSIS methodology is conducted to prioritize alternative energy strategies. We discuss the obtained results for the development of long-range alternative energy strategies. The results showed that turning the country into an energy hub and an energy terminal by effectively using the geo-strategic position within the framework of the regional cooperation is the most important priority. On the other hand, using the nuclear energy technologies within the energy supply strategies found to be the least favored priority.

1. Introduction

Energy is an indispensable resource for all human activities—used in different facets of life such as cooking, heating, cooling, lighting, transportation, and production/manufacturing. Energy projections have shown that the need for energy has grown significantly for the last couple of decades, and is expected to maintain such an increasing trend. According to Energy Industry Agency, world energy consumption will increase 56% by 2040 [13]. Increasing demand and the ever so expanding gap between energy production and consumption could lead to global energy crisis, if not dealt properly in a timely manner. Increasing population, industrialization and urbanization force governments to re-make strategic decisions to meet the increasing energy demands. Many countries, including Turkey, have developed energy action plans to address the issue and to mitigate the potential impact of energy shortages.

Energy consumption of most every country on the face of the earth has been dependent on the fossil fuels that include petroleum, coal and natural gas, but the reserves of fossil fuels are limited and non-renewable (this is true even if we consider the latest developments in the oil and gas production industry—i.e., fracking). It is a common belief that in order to sustain daily lives in a reliable way, we need to minimize the usage rate of fossil fuels, since fossil fuels damage the ecosystem and can cause and accelerate the global warming phenomenon. Because of this, renewable energy and related sources/procedures have been gaining increasingly more attention. Awareness of environmental issues, depleting fossil fuels resources, the precarious nature of dependency on fossil fuel/oil imports laid the foundation for the recent interest in the exploitation of renewable energy sources [19]. Renewable energy is deemed to be clean, sustainable, cost-effective, reliable and environmental friendly, and hence can be relied on for the long-term.

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Recently, Turkey has experienced a rapidly growing energy market because of the fact that there is an abundance of potential renewable energy sources (both type and magnitude). Further, geopolitical and geostrategic position of Turkey creates a rather unique posture for it in the international arena. Turkey is a transit country in the field of energy. It acts as a bridge between the world's crucial supply and demand regions. Additionally, Turkey is the 17th largest economy in the world and the 6th largest economy in Europe in terms of gross domestic product [48]. In order to increase its international effectiveness in this framework, Turkey has put forward several planning, implementations, investment projections, and related actions plans about its long-term energy policy. Out of them all, one of the most significant global policy initiative is the Vision 2023 Report, which is focused on Turkish energy sector and presents renewable energy investment options until 2023. As stated in this report, the current 70 gigawatt (GW) installed electricity capacity is expected to reach 120 GW by 2023 to meet the growing need for energy. According to Turkey's Strategic Energy Planning for 2023, 30% of total electricity production will come from renewable resources: 20,000 megawatt (MW) capacity of wind power plant, 3000 MW of solar energy capacity, 600 MW geothermal, 1500 MW installed capacity for biomass energy are expected to reach by 2023 [38].

In order to deal with the rapidly increasing energy demand it is necessary to develop alternative energy policies and prioritize these policies and projections objectively with scientific methods and feasibility studies. Nowadays, authorities who are responsible for energy management, feel the pressure to realign their strategies/priorities with solutions that are guided by the sustainability criteria. Energy planning is the complex process of determining the long-term energy resources (considering their capabilities and energy potentials of various regions) under the constraints of technological limitations, budget restrictions, conflicting objectives (some of which may be geo-politically motivates) and a number of criteria (most of which are vague, yet critical). At the end, it is a multi-dimensional complex decision making problem that consists of variety of decision makers from a wide variety of background/worldviews such as economical, ecological, social and technological [35]. The complex nature of the energy planning process requires the use of multi-criteria decision making (MCDM) approaches which are shown to be highly promising tools capable of solving similar management and planning problems [52,53]. Therefore, MCDM methods are very attractive approaches for energy planning problems, and recently their popularity has grown among scholars owing to their high level of effectiveness.

Due to the importance of energy resources in today's competitive environment, the selection of the "right" energy policy is a critical and complex decision problem. With this study, we propose an Analytic Network Process (ANP) weighted fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) methodology to overcome the complexities of this decision-making process. Even though the literature includes a number of studies where ANP and TOPSIS techniques are used individually or in some combination, this study offers additional contributions to the extant literature. First, it offers a systematic, easy to follow and implement, three-stage MCDM methodology that consists of Strengths, Weaknesses, Opportunities, and Threats (SWOT), ANP, and fuzzy TOPSIS. Second, although there are many successful applications of TOPSIS and/or ANP to a wide range of MCDM problems in various industries/fields, there is no application of a SWOT-based ANP-weighted fuzzy TOPSIS methodology for the energy policy selection problem. The hybrid-holistic methodology, a combination of the SWOT and ANP-weighted fuzzy TOPSIS, proposed herein (also shown with the application case) provides a satisfactory solution to the above-stated complex strategic decision-making process.

The rest of the paper is organized as follows. Section 2 reviews some of the most relevant recent studies on energy planning. General overview of Turkey's energy planning is given in Section 3. The fundamentals about SWOT, ANP and fuzzy TOPSIS are explained in Section 4. The proposed integrated methodology is presented and implemented in Section 5 and Section 6, respectively. A sensitivity analysis is applied in Section 7. Finally, the conclusions and future research directions of the study are given in Section 8.

2. Literature review

Energy policies are among the most crucial government endeavors as they help manage (and optimize) energy capacity options effectively for current needs/conditions as well as for future requirements in a reliable way. The existing literature shows a growing interest in studies that deal with energy planning, energy policies and energy politics, and most of them also mentioned the future directions of energy sources to address the need for sustainable, reliable, clean and inexpensive renewable energy. In a recently published study, Liao [29] analyzed Chinese wind energy policies—first providing a detail description of the depth and breadth of these policies, followed by a comparative analysis of various policy instruments such as regulation control and goal-planning which are applied by the Chinese government. There are also several recent studies in the literature focusing on the Turkish energy policy. Elsland et al. [14] evaluated Strategic Energy Efficiency Plan of Turkey, which is a roadmap for energy efficiency policy in all sector, while Basaran et al. [6] discussed the renewable energy capacity of Turkey and provided some feedbacks about the energy policy of Turkey and European Union under promising concept. Benli [9], Şekercioğlu and Yılmaz [39], and Aydin et al. [3] investigated the current potential of energy resources in Turkey under sustainability and environmental criteria framework in energy policy.

MCDM tools has been the most commonly utilized analytic approaches since the nature of energy planning problems is rather complex and multi-faceted. According to the related literature, Analytic Hierarchy Process (AHP), ANP, Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), Elimination and Choice Expressing the Reality (ELECTRE) are among the most commonly used MCDM techniques for energy policy applications [35]. ANP is an improved more expressive version of the AHP method as it allows feedback between the layers and accommodates interdependence among criteria [26]. There exists only a few studies using ANP on energy planning in the literature. For instance, Atmaca and Basar [2], Catron et al. [10] used ANP model to determine the best energy option from a sustainable development perspective. Ishizaka et al. [24], Strantzali and Aravossis [43], Singh and Nachtnebel [42], Wang et al. [54], Watson and Hudson [55], Luthra et al. [30,31], Prasad et al. [36], and Kahraman et al. [27] used various MCDM tools in order to select the best renewable energy option or to evaluate long-term energy planning models in order to help policy makers in better understanding of energy planning problems.

It is obvious that the energy planning problems can demonstrate an ambiguous and uncertain structure since it involves input from many stakeholders from various backgrounds and try to satisfy the demands with conflicting objectives. Several studies in the recent literature have attempted to employ fuzzy sets theory in various energy planning problems: Erol et al. [16], Luthra et al. [30,31], and Fetanat and Khorasaninejad [17] proposed fuzzy MCDM approach in order to show sustainability assessment of energy systems. Within the context of renewable energy, Suganthi et al. [44], Onar et al. [34], Zhang et al. [62], Tasri and Susilawati [45], and Wu et al. [56] applied a Fuzzy MCDM approach to determine for alternative renewable energies. In fuzzy TOPSIS, linguistic preferences can easily be converted to fuzzy numbers and be used in the calculations [11]. Since it has some superior features such as simple and fast computations, and tolerating/handling the uncertainty, a number of fuzzy TOPSIS applications have been employed to address energy planning problems. Choudhary and Shankar [12], Toosi and Samani [50], Şengül et al. [40], Guo and Zhao [18], and Erdoğan and Kaya

[15] utilized fuzzy TOPSIS method to determine the most appropriate energy alternative in energy planning procedure.

SWOT analysis is one of the most reliable, and most commonly used strategic planning tools. It allows managers to investigate the situation by defining external opportunities and threats and internal strengths and weaknesses in order to develop an action plan [1]. Since energy planning contains strategic decisions that are at high level of importance, there have been several use cases of SWOT analysis for these types of problems in the literature. Jaber et al. [25], Okello et al. [33], Zare et al. [61], Baş (2013) and Terrados et al. [47] utilized a SWOT analysis in order to form a renewable energy plan and strategic goals. This study aims to leverage the best practices reported in the literature to design and develop a capable/flexible framework to address the energy-planning problem.

3. An overview of Turkey's energy planning situation

Energy planning has emerged as a crucial and challenging problem for countries since the right resource allocation requires strategic decisions that involve careful planning of energy needs, which can be satisfied first from the domestic/national resources and then from the outside/imported sources.

Turkish government has developed a Strategic Energy Efficiency Plan as a potential roadmap to overcome the increasing energy demand [38]. The plan aims to set some strategic goals for reaching a well-designed energy policy under some contemporary concepts such as sustainability, reliability, environment-friendly and affordability by 2023. Turkey has various type of energy sources with a total installed power capacity of 74 GW (Fig. 1). As seen in the energy perspective of Turkey, the share of fossil fuels is rather large and need to be reduced in order to ensure energy security and long-term sustainability. Turkey currently depends on foreign energy, importing 72% of its energy (in the form of oil, natural gas and coal). Under these conditions, the government decided to construct nuclear power plants to sustain uninterrupted energy supply for the future. The first power plant is being built in Mersin-Akkuyu and is expected to be completed by 2020. The geographic position and climatic conditions of Turkey are highly conducive to utilization of renewable energy sources, making Turkey one of the top countries with substantially rich renewable energy potentials.

Attractive wind regions and total sunshine duration provides ample opportunities to clean energy production from domestic resources, and Turkish government aims to install wind capacity of up to 20 GW and to reach 3 GW of solar energy capacity by 2023 [49]. Turkey ranks seventh in the world and first in Europe in terms of geothermal energy [20]. According to renewable energy policy, the government aims to implement 600 megawatt electric (MWe) geothermal, 1500 MWe biomass and 34 GW hydropower to generate its electrical energy by 2023. The aim of energy policy is to heavily investing in renewable energy resources to contribute the ecological balances and also to avoid dependence on energy imports.

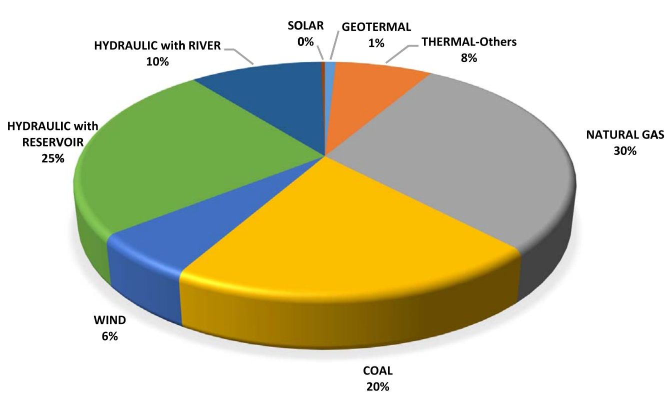

Fig. 1. Total Installed Power of Turkey [46].

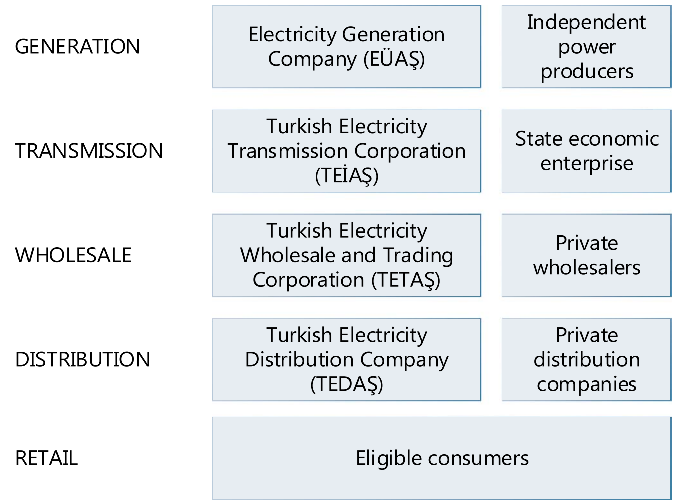

Fig. 2. The structure of the Turkish Electricity Market [46].

Turkey electricity market has a hierarchical structure, which consist of a large number of energy players to coordinate electricity from generation to retail processes. The Ministry of Energy and Natural Researches, The General Directorate of Energy Affairs, The Energy Market Regulatory Authority are just a few crucial actors of Turkish energy institutions, and they work in coordination to carry out preparation and implementation of energy policies and programs in an effective and strategic way [23]. The Energy Market Regulatory Authority is an independent regulator to provide licenses for all market activities from generation to distribution processes of Turkish electricity market. Fig. 2 provides a general perspective about the structure of electricity mechanisms in Turkey.

The above-mentioned picture of the Turkish energy market gives rise to the necessity on accurate and timely energy planning and policy making/evaluation. Due to its multi-dimensional nature, there is not a simple and universal response to the problem of energy planning that Turkey can directly adopt [51]. Energy planning is the process of developing long-range policies that guide the future of local, national, regional or even global energy systems [8].

4. An overview of the methods employed

We used SWOT analysis to identify all of the relevant factors, which can then be grouped into strengths (S), weaknesses (W), opportunities (O), and threats (T) according to internal and external perspectives. We employed an ANP approach to determine the weights of each SWOT factors and sub-factors. Then we used fuzzy TOPSIS method to properly rank the alternative strategies. The methods employed are briefly described in the following sections.

4.1. SWOT analysis

The SWOT analysis is a powerful strategic tool for evaluating an organizing internal and external key factors [5]. This method determines the best combination of strategies that maximizes the strengths and opportunities and minimizes the weakness and threats, and hence provides an excellent basis for strategy formulation when it is used properly.

In spite of the broad application of SWOT analysis, the main limitation of SWOT analysis is that the importance of each factor in the decision-making cannot be measured quantitatively. In other words, one of the drawbacks in SWOT analysis is to determine how to objectively rank the strategies and factors. If it is integrated with ANP, SWOT analysis can provide a quantitative measure for each factor of the decision making [28].

Table 1
SWOT analysis matrix.

		Internal Factors	
		Strengths (S)	Weaknesses (W)
External Factors	Opportunities (O)	SO strategy	WO strategy
	Threats (T)	ST strategy	WT strategy

Generally speaking, SWOT analysis has two main steps: the formation of the SWOT matrix, and determination of the strategies using the SWOT matrix. The formation of the SWOT matrix has two main steps: listing the key internal strengths and weaknesses, and listing the key external opportunities and threats. As shown in Table 1, the SWOT analysis matrix offers four types of strategies. After identifying the strength, weakness, opportunity and threat factors, the SWOT matrix is developed based on their combinations—manifesting into four pair wise SO, ST, WO and WT of strategies [21]. In the strategies identified as SO, the optimal use of internal strengths and external opportunities are determined. In the strategies identified as WO, the use of external opportunities would reduce or eliminate internal weaknesses. In the strategies identified as ST, the use of internal strengths would reduce or completely eliminate external threats. The strategies identified as WT, the decrease of external threats would be achieved by considering internal weaknesses [1].

4.2. Analytic network process method

ANP method is an extension of the AHP [37]. Often, highly complex decision making problems cannot be clarified just in a unidirectional hierarchical structure (as is the case in AHP), and hence the complex and multi-dimensional relationships between alternatives and criteria need to be captured, as is the case in ANP, where all of the elements and relationships are determined as one way, two-way interactions and loops. ANP generalizes the pairwise comparison process to judge each component by including priorities of criteria and alternatives.

The ANP model comprises of four main parts: the first part consists of defining problem comprehensively in a network model. The second part is to generate pairwise comparisons to estimate the relative importance of various elements at each level. The third part is to construct the super matrix to show priorities of elements. The last part is to make decisions according to the super matrix model [58]. During the ANP analysis, after obtaining relative importance of all components with the super matrix, a weighted super matrix is often used to normalize the super matrix values, and also a limit matrix is constructed for each cluster. The results of the decision problem are then obtained from the respective limit matrix [60]. A comparison of AHP and ANP methods is presented in Fig. 3. In AHP, the hierarchical structure starts with a goal at the top, and propagates through several levels of elements and connections between them in a top-down manner. It has no inner connections/dependence and no feedback from lower to higher levels.

The network model used in the second part of the model for SWOT analysis is composed of four levels (or groups of elements) as shown in Fig. 3. The “goal”, which is to find the best strategy is at the first level, deriving the rest of the hierarchy/network structure. SWOT factors and SWOT sub-factors, which are used as criteria and sub-criteria, are at the second and third level, respectively. The “Alternatives” which are composed of the alternative strategies are at the last level. Fig. 3a) shows a hierarchical representation of the SWOT model and Fig. 3b) shows its general network representation. The network model illustrates the case of a hierarchy with inner dependence within clusters, but no feedback. Here, instead of criteria, sub-criteria and alternatives, SWOT factors, SWOT sub-factors and alternative strategies are used respectively, and hence the SWOT factors can have inner dependencies.

Based on Fig. 3a), the super matrix of a SWOT hierarchy with four levels can be represented as follows:

$$W = \begin{array}{c} \text{Goal} \\ \text{SWOT factors} \\ \text{SWOT sub}-\text{factors} \\ \text{Alternatives} \end{array} \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & 0 & 0 & 0 \\ 0 & W_{32} & 0 & 0 \\ 0 & 0 & W_{43} & I \end{bmatrix}$$

In the matrix, W_{21} is a vector which represents the impact of the goal on the criteria, W_{32} is a vector which represents the impact of the criteria on each of the sub-criteria, W_{43} is a vector which represents the impact of the sub-criteria on each and every one of the alternatives, and I is the identity matrix.

Based on Fig. 3b), the general sub-matrix notation for the SWOT model used in this study can be shown as follows:

$$W = \begin{array}{c} \text{Goal} \\ \text{SWOT factors} \\ \text{SWOT sub}-\text{factors} \\ \text{Alternatives} \end{array} \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_1 & W_2 & 0 & 0 \\ 0 & W_3 & 0 & 0 \\ 0 & 0 & W_4 & I \end{bmatrix}$$

where, W_1 is a vector that represents the impact of the goal on the SWOT factors, W_2 is a matrix that represents the impact of the factors on each of the sub-factor, W_3 is a matrix that represents the impact of the sub-factors on each of the alternatives, and I is the identity matrix.

In this study, an ANP method is preferred and employed to formulate the multicriteria fuzzy structure that exists in the strategic energy planning problem, since it considers interrelations and feedbacks of SWOT matrix factors in a more realistic way. Then fuzzy TOPSIS methodology can be applied to determine the most appropriate alternative in a comprehensive manner using the opinions/inputs of the energy sector experts by allowing them to express their views with linguistic variables. The fuzzy TOPSIS methodology provide better performance over its classical form (plain TOPSIS) due to the fact that the classical method can not handle the imprecision usually exists in human language and related decision making processes.

4.3. Fuzzy set theory

The fuzzy set theory was first proposed by Zadeh [59] and has been applied to diverse fields. In the fuzzy set theory, the value of and element is determined via the membership of the element to a fuzzy set—resulting in a value between zero and one (and not just zero or one). Some basic concepts of fuzzy sets are as follows.

Definition 1. ***(Fuzzy Set—FS)***

Let X is a set (space), with generic element of X denoted by x, that is $X = \{x\}$. Then a FS is defined as Eq. (1).

$$A = \{\langle x, \mu_A(x)\rangle | x \in X\} \tag{1}$$

where $\mu_A : X \rightarrow [0, 1]$ is the membership function of the FS A, $\mu_A(x) \in [0, 1]$ is the degree of membership of the element x to the set A.

Definition 2. ***(Triangular Fuzzy Number-TFN)***

TFN is represented as triplet $\widetilde{A} = [a_1, a_2, a_3]$, where a_1, a_2, a_3 are crisp numbers. The membership function of $\widetilde{A}$ is defined as in Eq. (2)

$$f_{\widetilde{A}}(x) = \begin{cases} 0 & x < a \\ \frac{x-a_1}{a_2-a_1} & a_1 \le x < a_2 \\ \frac{a_3-x}{a_3-a_2} & a_2 \le x < a_3 \\ 0 & x > a_3 \end{cases} \tag{2}$$

4.4. Fuzzy TOPSIS method

TOPSIS approach was first developed by Hwang and Yoon [22]. Unlike other methods, TOPSIS provides a basic concept based on the shortest distance from positive ideal solution and farthest distance

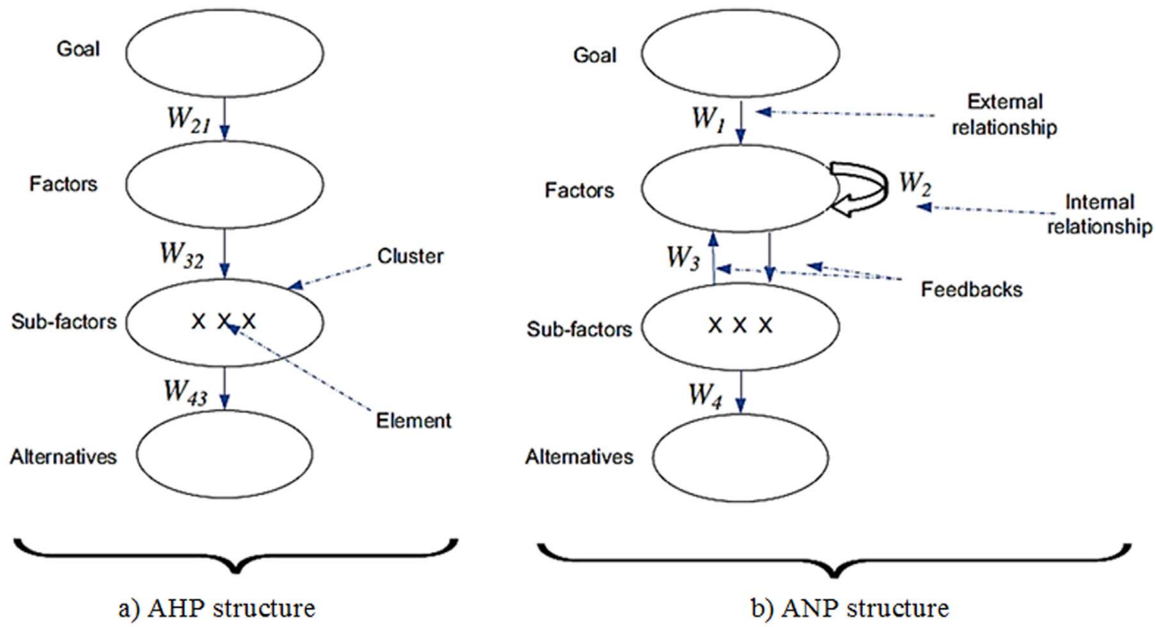

Fig. 3. A comparison of AHP and ANP methods [60].

from the negative ideal solution. Fuzzy TOPSIS provides an advantageous way to deal with incomplete and uncertain information due to the increasing complexity of the energy policy decisions under fuzzy environment. In fuzzy TOPSIS method, the criteria weights are not crisp owing to the vagueness of inherent subjective nature of human thinking.

Definition 3. Let $\widetilde{A} = (a_1, a_2, a_3)$, $\widetilde{B} = (b_1, b_2, b_3)$ be two fuzzy numbers, so their mathematical relations can be defined as:

$$\widetilde{A} \oplus \widetilde{B} = (a_1, a_2, a_3) \oplus (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3); \quad (3)$$

$$\widetilde{A} \otimes \widetilde{B} = (a_1, a_2, a_3) \otimes (b_1, b_2, b_3) = (a_1 b_1, a_2 b_2, a_3 b_3); \quad (4)$$

Definition 4. Let $\widetilde{A}_i = (a_{i1}, a_{i2}, a_{i3})$ be a triangular fuzzy number for i $\in I$. Then the normalized fuzzy number of each $\widetilde{A}_i$ is expressed as

$$\widetilde{R} = [r_{ij}]_{m\times n}, \qquad i = 1, 2, \ldots, m \qquad j = 1, 2, \ldots, n,$$

for benefit-type criteria, the normalization processing is expressed as Eq. (5):

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in B; \quad (5)$$

for cost-type criteria, the normalization processing is expressed as Eq. (6):

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \quad j \in C; \quad (6)$$

$$c_j^* = \max_i c_{ij} \qquad j \in B;$$

$$a_j^- = \min a_{ij} \qquad j \in C;$$

where B and C are the sets of benefit criteria and cost criteria.

Definition 5. The distance between two TFNs $\widetilde{A} = (a_1, a_2, a_3)$, $\widetilde{B} = (b_1, b_2, b_3)$ can be defined by the Euclidean distance as follows [11]:

$$d(\widetilde{A}, \widetilde{B}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad (7)$$

Definition 6. Linguistic variable is an easy way to describe complex or ill-defined situations by transforming it into quantitative expressions. The fuzziness of human thought results in decision making with linguistic evaluations [57]. Several representations of linguistic variables are possible. An example of transformation rules between the linguistic terms and fuzzy numbers is given in Table 2 [11].

5. Proposed methodology

The proposed integrated framework that we have employed in this study is graphically depicted in Fig. 4. With regards to incorporating current energy policies, strategies, environmental concerns and global tendencies, a general structure for energy planning framework was developed. Then, the key factors are defined in the context of SWOT analysis, and the SWOT factors are then incorporated into the integrated ANP weighted fuzzy TOPSIS framework for the formulation of the strategy plan.

The study should be considered as a long-term energy planning model of a country, and it may require a considerable time schedule for carrying out the individual stages of the proposed model to achieve the envisioned goal. In this study, as illustrated in Fig. 4, there are three main stages to assess Turkey's Vision 2023 goals. Time wise, we estimate that two months was spent on Stage 1, three months on Stage 2, and three months on Stage 3, in total eight months was spent to realize all required procedures. Depending on the unforeseen circumstances, such and difficulty in identifying and recruiting knowledge experts and policy makers, this total project time may be as long as a year.

The steps of the proposed framework can be briefly as follows,

Table 2
Transformation rules of linguistic variables.

Linguistic variable	Triangular fuzzy number
Very low (VL)	(0,0,1)
Low (L)	(0,1,3)
Medium low (ML)	(1,3,5)
Fair (F)	(3,5,7)
Medium high (MH)	(5,7,9)
High (H)	(7,9,10)
Very High (VH)	(9,10,10)

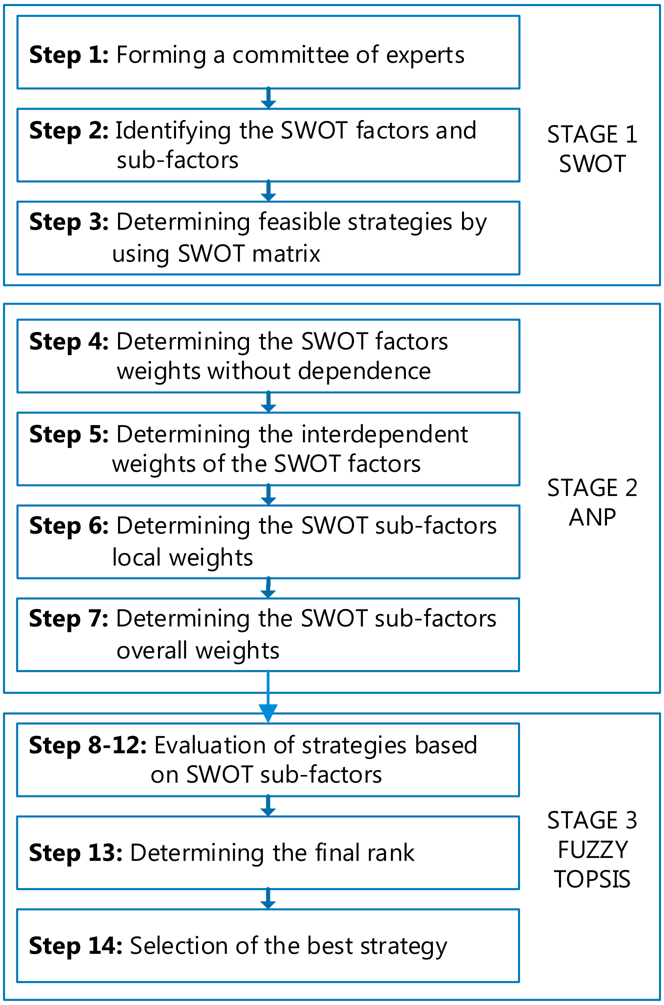

Fig. 4. The integrated framework proposed in the paper.

which is partially adapted from the best practices in the extant literature [11,28,41,7]:

Step 1. Form a committee of experts and/or decision makers.

Step 2. Determine the SWOT matrix by defining SWOT factors and sub-factors.

Step 3. Identify feasible strategies by using the SWOT matrix.

Step 4. Construct pairwise comparisons of the SWOT factors using the 1–9 scale with respect to the objective (W_1).

Step 5. Determine the inner dependence among the SWOT factors and obtain the relative importance weights (W_2). Then, calculate the interdependent weights of the SWOT factors ($w_{factors} = W_2 * w_1$).

Step 6. Construct the local importance degrees of the SWOT sub-factors ($w_{\text{sub-factors(local)}}$).

Step 7. Determine the overall weights of the SWOT sub-factors ($w_{\text{sub-factors(overall)}}$).

Step 8. Obtain the evaluation matrix with regarding to identified alternatives and SWOT sub-factors with linguistic variable which performed by expert team.

Step 9. Obtain normalized linguistic variable. The normalized fuzzy decision matrix denoted by $\tilde{R}$ is shown as the following formula:

$$\tilde{R} = [r_{ij}]_{m\times n}, \qquad i = 1, 2, \ldots, m \qquad j = 1, 2, \ldots, n,$$

Then, perform the normalization process by the following the following formula for benefit-type criteria

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \qquad j\in B$$

And following the following formula for cost-type criteria

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \qquad j\in C.$$

Step 10. Obtain the weighted normalized fuzzy decision matrix with respect to each SWOT sub-factors. The weights of each criterion is obtained from ANP method, and the weighted normalized fuzzy decision matrix is constructed as follows:

$$\tilde{V} = [\tilde{v}_{ij}]_{m\times n} \qquad i = 1, 2, \ldots, m \qquad j = 1, 2, \ldots, n$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes w_{ij} \tag{8}$$

where w_{ij} represents the weight of criterion C_j .

Step 11. Determine distance to fuzzy positive ideal solution ($FPIS, A^*$) and fuzzy negative ideal solution ($FNIS, A^-$) by using Eq. (5).

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*) \tag{9}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-) \tag{10}$$

where $\tilde{v}_j^* = (1, 1, 1)$ and $\tilde{v}_j^- = (0, 0, 0)$, j=1,2,...,n.

Step 12. Calculate closeness coefficient for each alternative by the following formula:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \ i = 1, 2, \ldots, m \tag{11}$$

Step 13. Rank the order of alternative strategies according to closeness coefficient.

Step 14: Select the best strategy.

6. Application of the proposed methodology to Turkey's energy sector

The proposed methodology was applied to Turkey's energy sector in order to determine the national energy strategic plan. Initially, we reviewed the literature to establish a comprehensive understanding of the strategic energy policy determinants. We then identified a rich and diverse committee of experts from the energy sector (both government and commercial). In this way, we wanted to make sure to include all factors and sub-factors that may have an effect on the optimal outcome. The SWOT analysis is a powerful strategic tool and it provides the means to identify and organize information on key issues that are important to achieving the objective. Hence, this analysis help identify the strengths and/or the weaknesses of the organization which are called as internal factors, and help uncover the opportunities and/or the threats towards the organization which are called as external factors. The main steps of the proposed methodology and its specific implementation are given below:

Step 1: A series of focus group meetings was conducted with government officials (from the Ministry of Energy), academicians, industry participants and other stakeholders in energy sector to determine their onions and preferences as they relate to the nature of the energy strategies and the evaluation methods of those strategies, expressed in free-form natural language using imprecise linguistic terms.

Step 2: A SWOT matrix was determined by carefully defining and verifying the SWOT factors and sub-factors. The constructed SWOT matrix based on the expert knowledge are presented in Table 3.

Step 3: Using the results of the SWOT analysis explained in Step 2, we identified all the factors that affect the Turkey's Energy Sector according to internal and external perspectives. We have leveraged the best practices about energy policies, programs and roadmaps reported in previous literature to augment the knowledge that we elicited from the domain experts through the interviews and focus group discussions. The idea/goal was to make the obtained knowledge as complete and relevant as possible. After determining the strengths, weaknesses, opportunities, and threats, nine alternative strategies were identified

Table 3
SWOT matrix for Turkey's energy sector [4].

Internal Factors		**STRENGTHS (S)**	**WEAKNESSES (W)**
External Factors		**S1**. Abundance of coal reserves **S2**. Height of potential of clean and renewable energy **S3**. Manpower at the engineering level **S4**. Entrepreneur industry structure **S5**. Potential of foreign investment	**W1.** Lack of planning on energy preferences **W2**. Lack of administrative coordination and adaptation efforts in energy, climate, and industrial applications **W3**. Weakness of the quality coal/lignite **W4**. Lack of trained manpower in the middle level **W5**. Bureaucratic obstacles and lack of legal infrastructure **W6**. Lack of cooperation and coordination among institutions **W7**. The scarcity of oil and natural gas reserves **W8**. Lack of funding for R & D activities
OPPORTUNITIES (O)	**O1**. Increased opportunities for regional cooperation **O2**. High potential for increasing energy efficiency **O3**. The opportunity to enter renewable energy technologies **O4**. The geopolitical location (proximity to fossil resources, growing markets, possibility of being energy bridge) **O5**. Abundance in alternatives of technology transfer, possibility to prefer tried and mature technologies **O6**. Turkey's rising image	**STRATEGIES (SO)** **SO1.** Increasing the share of the renewable energy resources within the energy supply **SO2**. Turning the country into an energy hub and terminal by using the geo-strategic position effectively within the framework of the regional cooperation processes	**STRATEGIES (WO)** **WO1**. Increasing Energy Efficiency **WO2**. Making the free market conditions operate fully and providing for the improvement of the investment environment **WO3**. Providing the diversity of resources in the area of oil and natural gas and taking the measures for reducing the risks due to importation **WO4**. Using the nuclear energy technologies within the energy supply
THREATS (T)	**T1**. Being open to outside interventions in economic, technological, political and scientific aspects **T2**. Rapid population growth, internal migration and unplanned urbanization **T3**. The high rate of import dependence in terms of primary energy resources **T4**. Monopolization of energy markets in the world **T5**. The rise in greenhouse gas emissions and the climatic change and the international obligations in such matters	**STRATEGIES (ST)** **ST1**. Providing diversity in resources by giving priority to the domestic resources **ST2**. Minimizing the negative environmental impacts of the activities in the energy area	**STRATEGIES (WT)** **WT1**. Increasing R & D activities in the energy area

from the SWOT analysis. Some of the alternative strategies that were identified in the SWOT analysis were already mentioned and partially accounted in the 2010–2014 Strategic Plan of the Ministry of Energy and Natural Resources [32]. As shown in Table 3, nine alternative strategies were obtained from the SWOT analysis. These strategies can be further detailed as follows:

6.1. Increasing the share of the renewable energy resources within the energy supply (SO1)

Turkey has a considerably high potential for some of the renewable energy resources, which may contribute to electricity energy production. Specifically, in the case of Turkey, wind, geothermal and hydroelectric energies can contribute to the energy supply/security of the country. For this reason, increasing the share of the renewable energy resources within the energy supply is one of the strategies that should be taken into account.

6.2. Turning the country into an energy hub and transport terminal by using its geo-strategic position effectively within the framework of the regional agreements/cooperation (SO2)

Turkey is positioned in a geography where about 72% of the proved oil and natural gas reserves of the world are buried—Middle East and the Caspian Basin. With the advantage offered by the geographical and geostrategic position of the country, becoming both a hub and a terminal in the transportation of the Middle Eastern and Central Asian oil and gas production to the world markets should be strategic target. This strategy may increase the regional and global influence of the country in the area of energy.

6.3. Increasing energy efficiency (WO1)

The improvement of the efficiency in the processes—in terms of the use of energy, the prevention of loss and the reduction of energy intensity—have a vital importance within the framework of energy conservation and energy independence hat should be covered within the energy planning process of Turkey. For this reason, increasing energy efficiency is one of the important strategies that contributes to whole process of energy planning.

6.4. Making the free market conditions operate fully to provide the necessary improvements for a better investment environment (WO2)

In Turkey, the rules and regulations that would enable the liberalization of the energy sector were created and implemented in 2001. The main goal of the liberalization of the energy sector is to create the type of investment environment that will attract much needed foreign (as well as domestic) investors, potentially resulting in a significant boost of exergy production which is necessary for the energy supply security. For this reason, improvement of the investment environment is an important strategy to include in the process of energy planning.

Table 4
The inner dependence matrix of the SWOT factors with respect to “Strengths”.

Strengths (S)	W	O	T	Relative importance weights
Weaknesses (W)	1	1/3	1	0.200
Opportunities (O)		1	3	0.600
Threats (T)			1	0.200

Table 5
The inner dependence matrix of the SWOT factors with respect to “Weaknesses”.

Weaknesses (W)	S	O	T	Relative importance weights
Strengths (S)	1	2	6	0.600
Opportunities (O)		1	3	0.300
Threats (T)			1	0.100

Table 6
The inner dependence matrix of the SWOT factors with respect to “Opportunities”.

Opportunities (O)	S	W	T	Relative importance weights
Strengths (S)	1	3	3	0.600
Weaknesses (W)		1	1	0.200
Threats (T)			1	0.200

Table 7
The inner dependence matrix of the SWOT factors with respect to “Threats”.

Threats (T)	S	W	O	Relative importance weights
Strengths (S)	1	3	1	0.429
Weaknesses (W)		1	1/3	0.142
Opportunities (O)			1	0.429

6.5. Providing the diversity of supply sources in the area of oil and natural gas, and hence taking the measures for reducing the risks of import interruptions (WO3)

Based on the energy consumption portfolio of Turkey, the rate of import dependence in natural gas was 97.3%, for the year 2008. In addition, oil and natural gas need of Turkey is covered by five countries, and two thirds of the importation is made from one country. Since, it is a risky situation to depend on one supply source, providing the necessary diversity of suppliers in the area of oil and natural gas, and taking the measures to reduce the risks due to importation disruptions is an important strategy to include in the overall planning process.

6.6. Using the nuclear energy technologies as an alternative domestic energy supply (WO4)

In order to provide diversification of the energy supply, in addition to maximum utilization of the domestic and renewable resources, the use of a nuclear power in energy supply is deemed to be important. For this reason, using the nuclear energy technologies within the energy supply is taken as an alternative strategy in the study.

6.7. Providing diversity in energy sources by giving priority to the domestic resources (ST1)

This strategy contributes to energy supply security. It covers the utilization of the all of the domestic resources, maximum use of the renewable energy resources, the increase of the diversification of the energy supply, and the integration of the nuclear energy into the electricity supply chain. By this way, redesigning the old/existing energy sourcing portfolio, which has been based on three main bases—coal, natural gas, and hydraulic—and therefore, reducing the import dependence is deemed to be a worthy strategic goal/target.

6.8. Minimizing the negative environmental impacts of the activities in the energy production (ST2)

This strategy contains the topics like improvement of energy efficiency (throughout the supply chain), widespread adoption and maximum utilization of renewable energy resources, the adaptation of clean coal combustion technologies, and the integration of the nuclear energy.

6.9. Increasing research and development (R & D) activities in the energy area (WT1)

Increasing R & D activities in the energy area helps countries like Turkey not only to adopt the existing best practices but also develop new and innovative ones that would fit specifically the needs/wants and the special characteristics of the country.

Step 4: Assuming that there is no dependence among the SWOT factors, a pairwise comparison of the SWOT factors with respect to the goal (using the 1–9 scale) is conducted. All pairwise comparisons were done with the inputs and guidance of the expert team.

Step 5: Inner dependence among the SWOT factors is determined by analyzing the impact of each factor on every other factor using pairwise comparisons. It is common to see the SWOT factors having dependent behaviors, therefore we used ANP which is a powerful tool to handle potential interdependencies. Based on the identified inner dependencies, pairwise comparison matrices are formed for the factors, and are shown in Tables 4–7.

Using the computed relative importance weights, the inner dependence matrix of the SWOT factors (W2) is constructed:

$$\mathbf{W_2} = \begin{bmatrix} 1 & 0.600 & 0.600 & 0.429 \\ 0.200 & 1 & 0.200 & 0.142 \\ 0.600 & 0.300 & 1 & 0.429 \\ 0.200 & 0.100 & 0.200 & 1 \end{bmatrix}$$

The interdependent priorities of the SWOT factors are calculated as follows:

$$\mathrm{w_{factors}} = \mathbf{W_2} \times \mathbf{w_1} = \begin{bmatrix} 1 & 0.600 & 0.600 & 0.429 \\ 0.200 & 1 & 0.200 & 0.142 \\ 0.600 & 0.300 & 1 & 0.429 \\ 0.200 & 0.100 & 0.200 & 1 \end{bmatrix} \times \begin{bmatrix} 0.333 \\ 0.167 \\ 0.333 \\ 0.167 \end{bmatrix} = \begin{bmatrix} 0.352 \\ 0.162 \\ 0.327 \\ 0.158 \end{bmatrix}$$

Step 6: In this step, the local importance degrees of the SWOT sub-factors ($\mathrm{w_{sub-factors(local)}}$) are calculated using the pairwise comparison matrix.

Step 7. Here, we determined the overall weights of the SWOT sub-factors ($\mathrm{w_{sub-factors(global)}}$) by multiplying the interdependent priorities of SWOT factors found in Step 5 with the local priorities of SWOT sub-factors obtained in Step 6. The priorities are shown in Table 8.

Step 8. In this step, we obtained the evaluation matrix, with regards to the alternatives and SWOT sub-factors, using the linguistic variables provided by the expert team (Table 9).

Step 9–10: Here, the weighted normalized fuzzy decision matrix with respect to each SWOT sub-factors is constructed, and is shown in Table 10.

Step 11–12. In this step, the fuzzy TOPSIS methodology was implemented to prioritize the evaluated SWOT factors. Closeness coefficients of SWOT factors were obtained and given in Table 11. According to the tabulated results, the second strategy had the highest closeness coefficient with the value of 0.0294. Accordingly, “SO2: Turning the country into an energy hub and terminal by using the

Table 8
Priorities of the SWOT factors and sub-factors.

SWOT factors	Priority of the factors	SWOT sub-factors	Priority of the sub-factors	Overall priority of the sub-factors
Strengths (S)	0.352	S1	0.159	0.056
		S2	0.327	0.115
		S3	0.050	0.018
		S4	0.196	0.069
		S5	0.269	0.095
Weaknesses (W)	0.162	W1	0.111	0.018
		W2	0.190	0.031
		W3	0.158	0.026
		W4	0.022	0.004
		W5	0.196	0.032
		W6	0.190	0.031
		W7	0.022	0.004
		W8	0.111	0.018
Opportunities (O)	0.327	O1	0.244	0.080
		O2	0.119	0.039
		O3	0.038	0.012
		O4	0.244	0.080
		O5	0.119	0.039
		O6	0.237	0.078
Threats (T)	0.158	T1	0.217	0.034
		T2	0.043	0.007
		T3	0.217	0.034
		T4	0.120	0.019
		T5	0.402	0.064

geo-strategic position effectively within the framework of the regional cooperation processes" came out as the best (most preferred/valued) strategy from the SWOT analysis.

Step 13. Here, we ranked the order of all alternatives according to closeness coefficient. The ranking of the alternatives in descending order came out to be Strategy 2, Strategy 8, Strategy 1, Strategy 3, Strategy 9, Strategy 7, Strategy 4, Strategy 5, and Strategy 6 (SO2 - ST2 - SO1 - WO1 - WT1 - ST1 - WO2 - WO3 - WO4).

Step 14. In this last step, the best strategy is determined as "Strategy 2 (SO2): Turning the country into an energy hub and terminal by using the geo-strategic position effectively within the framework of the regional cooperation processes".

According to the calculated ranking values illustrated with a bar-graph in Fig. 5, it can be concluded that Strategy 2 (SO2) is in the first/ highest priority. SO2 (turning the country into an energy hub and terminal by using its geo-strategic position effectively within the framework of the regional cooperation processes) ranked higher than the other strategies with a priority value of 0.0294. Strategy ST2 (minimizing the negative environmental impacts of the activities in the energy area) came as the second highest priority with a ranking value of 0.0260. Strategy SO1 (increasing the share of the renewable energy resources within the energy supply) is the third highest with a priority rank value of 0.0249 and the fourth one is WO1 (increasing energy efficiency) with priority rank value of 0.0231.

Strategy WT1 (increasing R & D activities in the energy area) is the fifth priority with a value of 0.0183, Strategy ST1 (providing diversity in resources by giving priority to the domestic resources) is the sixth one with a priority value of 0.0160, Strategy WO2 (making the free market conditions operate fully and providing for the improvement of the investment environment) is the seventh important alternative with a value of 0.0146. Strategy WO3 (providing the diversity of resources in the area of oil and natural gas and taking the measures for reducing the risks due to importation) ranks eighth priority with a value of 0.0134 and Strategy WO4 (using the nuclear energy technologies within the energy supply) has the lowest priority with a value of 0.0126. All the obtained results from the proposed integrated approach support the Vision 2023 energy policy, which is to achieve sustainable, reliable, independent and uninterrupted energy flow, all of which in harmony with the resource priorities of the energy policy of the country.

7. Sensitivity analysis

To investigate the level/strength of influence (i.e., sensitivity) of criteria weights to the ranking one the alternatives, we carried out a sensitivity analysis experiment. Using varying degrees of criteria weights, we measure the changes in the outcome. Specifically, five cases were examined using a sensitivity analysis framework, but the results (i.e., the ranked-order of alternative strategies) remained mostly the same (in some cases the ranking values/weights changed slightly without much impact on the rankings). The high-level SWOT factors weights (which are used as criteria weights in the examined cases) are given in Table 12, and the obtained sensitivity results for strategies

Table 9
Evaluation matrix.

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7	Strategy 8	Strategy 9
S1	VL	MH	ML	ML	MH	VL	H	M	MH
S2	MH	MH	L	L	MH	VL	MH	MH	L
S3	MH	L	MH	L	VL	ML	L	MH	MH
S4	H	H	H	ML	L	VL	L	ML	ML
S5	H	H	H	ML	VL	H	VL	VL	VL
W1	MH	MH	ML	L	MH	ML	MH	ML	L
W2	ML	ML	H	H	L	L	L	H	M
W3	ML	M	M	VL	VL	VL	H	H	H
W4	M	ML	MH	VL	VL	ML	MH	MH	MH
W5	MH	M	M	MH	L	L	M	M	VL
W6	H	H	ML	ML	L	VL	L	MH	ML
W7	ML	H	ML	VL	H	VL	M	MH	M
W8	M	VL	M	VL	M	ML	M	M	H
O1	M	H	M	VL	VL	M	VL	H	H
O2	VL	ML	H	H	ML	VL	ML	H	H
O3	H	ML	VL	H	ML	VL	ML	MH	MH
O4	M	VH	L	L	L	L	M	VH	L
O5	H	L	H	L	ML	ML	ML	MH	VL
O6	ML	H	ML	M	ML	M	VL	MH	M
T1	L	H	H	ML	H	MH	L	L	L
T2	L	L	VH	L	L	L	M	VH	L
T3	M	H	L	M	L	L	H	ML	M
T4	ML	MH	MH	MH	ML	VL	MH	L	ML
T5	H	ML	H	ML	VL	ML	VL	MH	H

Table 10
Fuzzy weighted decision matrix.

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7	Strategy 8	Strategy 9
S1	(0,0,0.01)	(0.03,0.04,0.05)	(0.01,0.02,0.03)	(0.01,0.02,0.03)	(0.03,0.04,0.05)	(0,0,0.01)	(0.04,0.05,0.06)	(0.02,0.03,0.04)	(0.03,0.04,0.05)
S2	(0.06,0.09,0.12)	(0.06,0.09,0.12)	(0,0.01,0.04)	(0,0.01,0.04)	(0.06,0.09,0.12)	(0,0,0.01)	(0.06,0.09,0.12)	(0.06,0.09,0.12)	(0,0.01,0.04)
S3	(0.01,0.01,0.02)	(0,0,0.01)	(0.01,0.01,0.02)	(0,0,0.01)	(0,0,0)	(0,0.01,0.01)	(0,0,0.01)	(0.01,0.01,0.02)	(0.01,0.01,0.02)
S4	(0.05,0.06,0.07)	(0.05,0.06,0.07)	(0.05,0.06,0.07)	(0.01,0.02,0.03)	(0,0.01,0.02)	(0,0,0.01)	(0,0.01,0.02)	(0.01,0.02,0.03)	(0.01,0.02,0.03)
S5	(0.07,0.09,0.09)	(0.07,0.09,0.09)	(0.07,0.09,0.09)	(0.01,0.03,0.05)	(0,0,0.01)	(0.07,0.09,0.09)	(0,0,0.01)	(0,0,0.01)	(0,0,0.01)
W1	(0.01,0.01,0.02)	(0.01,0.01,0.02)	(0,0.01,0.01)	(0,0,0.01)	(0.01,0.01,0.02)	(0,0.01,0.01)	(0.01,0.01,0.02)	(0,0.01,0.01)	(0,0,0.01)
W2	(0,0.01,0.02)	(0,0.01,0.02)	(0.02,0.03,0.03)	(0.02,0.03,0.03)	(0,0,0.01)	(0,0,0.01)	(0,0,0.01)	(0.02,0.03,0.03)	(0.01,0.02,0.02)
W3	(0,0.01,0.01)	(0.01,0.01,0.02)	(0.01,0.01,0.02)	(0,0,0)	(0,0,0)	(0,0,0)	(0.02,0.02,0.03)	(0.02,0.02,0.03)	(0.02,0.02,0.03)
W4	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
W5	(0.02,0.02,0.03)	(0.01,0.02,0.02)	(0.01,0.02,0.02)	(0.02,0.02,0.03)	(0,0,0.01)	(0,0,0.01)	(0.01,0.02,0.02)	(0.01,0.02,0.02)	(0,0,0)
W6	(0.02,0.03,0.03)	(0.02,0.03,0.03)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0,0.01)	(0,0,0)	(0,0,0.01)	(0.02,0.02,0.03)	(0,0.01,0.02)
W7	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
W8	(0.01,0.01,0.01)	(0,0,0)	(0.01,0.01,0.01)	(0,0,0)	(0.01,0.01,0.01)	(0,0.01,0.01)	(0.01,0.01,0.01)	(0.01,0.01,0.01)	(0.01,0.02,0.02)
O1	(0.02,0.04,0.06)	(0.06,0.07,0.08)	(0.02,0.04,0.06)	(0,0,0.01)	(0,0,0.01)	(0.02,0.04,0.06)	(0,0,0.01)	(0.06,0.07,0.08)	(0.06,0.07,0.08)
O2	(0,0,0)	(0,0.01,0.02)	(0.03,0.03,0.04)	(0.03,0.03,0.04)	(0,0.01,0.02)	(0,0,0)	(0,0.01,0.02)	(0.03,0.03,0.04)	(0.03,0.03,0.04)
O3	(0.01,0.01,0.01)	(0,0,0.01)	(0,0,0)	(0.01,0.01,0.01)	(0,0,0.01)	(0,0,0)	(0,0,0.01)	(0.01,0.01,0.01)	(0.01,0.01,0.01)
O4	(0.02,0.04,0.06)	(0.07,0.08,0.08)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.02,0.04,0.06)	(0.07,0.08,0.08)	(0,0.01,0.02)
O5	(0.03,0.03,0.04)	(0,0,0.01)	(0.03,0.03,0.04)	(0,0,0.01)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.02,0.03,0.03)	(0,0,0)
O6	(0.01,0.02,0.04)	(0.05,0.07,0.08)	(0.01,0.02,0.04)	(0.02,0.04,0.05)	(0.01,0.02,0.04)	(0.02,0.04,0.05)	(0,0,0.01)	(0.04,0.05,0.07)	(0.02,0.04,0.05)
T1	(0,0,0.01)	(0.02,0.03,0.03)	(0.02,0.03,0.03)	(0,0.01,0.02)	(0.02,0.03,0.03)	(0.02,0.02,0.03)	(0,0,0.01)	(0,0,0.01)	(0,0,0.01)
T2	(0,0,0)	(0,0,0)	(0.01,0.01,0.01)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0.01,0.01,0.01)	(0,0,0)
T3	(0.01,0.02,0.02)	(0.02,0.03,0.03)	(0,0,0.01)	(0.01,0.02,0.02)	(0,0,0.01)	(0,0,0.01)	(0.02,0.03,0.03)	(0,0.01,0.02)	(0.01,0.02,0.02)
T4	(0,0.01,0.01)	(0.01,0.01,0.02)	(0.01,0.01,0.02)	(0.01,0.01,0.02)	(0,0.01,0.01)	(0,0,0)	(0.01,0.01,0.02)	(0,0,0.01)	(0,0.01,0.01)
T5	(0.04,0.06,0.06)	(0.01,0.02,0.03)	(0.04,0.06,0.06)	(0.01,0.02,0.03)	(0,0,0.01)	(0.01,0.02,0.03)	(0,0,0.01)	(0.03,0.04,0.06)	(0.04,0.06,0.06)

from the sensitivity analyses are shown in Table 13. Therein, the first case is the baseline (the current order/value of the alternatives) while the others are the outcomes of the sensitivity analysis.

According to the results shown in Table 13, where the new cases are compared against the baseline (i.e., the Case 1), the comparative results for Case 2 and In Case 3 remained exactly same. In Case 4, only the order of Strategy 1 and 3 has changed while in Case 5, the order of Strategy 1, Strategy 3 and Strategy 8 had changed. In any of the other cases, there were not any changes in the priority order of the alternative strategies.

8. Discussion and conclusions

In recent years, strategic energy planning problems have been a hot topic in the literature. Energy decisions are very crucial for governments because of their potential impact (positive or negative) on many facets of the governance and well-being/prominence of the country as a whole. Due to its strategic importance, the governments are trying very hard to effectively and accurately align and manage their energy policies. In order for the governments to take advantage of the opportunities and at the same time to eliminate or mitigate (minimize the impact of) the negative outcomes, they need to diligently and carefully plan (and continuously re-plan) their energy policies, not just in short terms but also at the strategic level, in order to forecast and address the ever so rapidly changing energy market conditions.

The government of Turkey put forward some rather dramatic/futuristic energy policies, strategies, and regulations to address the increasing energy demand and to avoid possible energy bottlenecks in the middle-to-long term. In order to reduce energy dependence to foreign sources, some critical implementations have been carried out. The Vision 2023 is one of the major energy policies developed by/for Turkey to reach the determined energy targets. According to this roadmap, Turkey aims to build 600 MW geothermal capacity, 3000 MW solar power capacity and 20,000 MW wind power capacity, and have them all in operation by 2023. It should be noted that technological investments are critically important along with the natural resources (i.e., climatic conditions) in order to utilize the available energy sources.

With the study, reported in this paper, we proposed an integrated framework for the Turkey's energy sector using the SWOT analysis augmented with the ANP methodology to obtain criteria weights, and fuzzy TOPSIS methodology to prioritize alternative energy strategies. According to the results of the SWOT-ANP weighted fuzzy TOPSIS analytic methodology, turning the country into an energy hub and an energy terminal by using the geo-strategic position effectively within the framework of the regional cooperation processes (SO2) ranks as the first priority. The main reason that makes this strategy very important is the Turkey's strategic and geopoetical location. Turkey is a natural “energy bridge” between the major oil producing regions in the Middle East and Caspian Sea on the one hand and consumer markets in Europe on the other. This area is not only geographically but also economically very important. For this reason, the study results are in line with the target of becoming both a hub and a terminal in the transportation of the

Table 11
Fuzzy TOPSIS results.

Strategies	Distance to the PIS	Distance to the NIS	Closeness coefficients of each strategy	Ranking of strategies
Strategy 1 (SO1)	23.43	0.60	0.0249	3
Strategy 2 (SO2)	23.31	0.71	0.0294	1
Strategy 3 (WO1)	23.47	0.56	0.0231	4
Strategy 4 (WO2)	23.69	0.35	0.0146	7
Strategy 5 (WO3)	23.71	0.32	0.0134	8
Strategy 6 (WO4)	23.73	0.30	0.0126	9
Strategy 7 (ST1)	23.65	0.38	0.0160	6
Strategy 8 (ST2)	23.40	0.62	0.0260	2
Strategy 9 (WT1)	23.59	0.44	0.0183	5

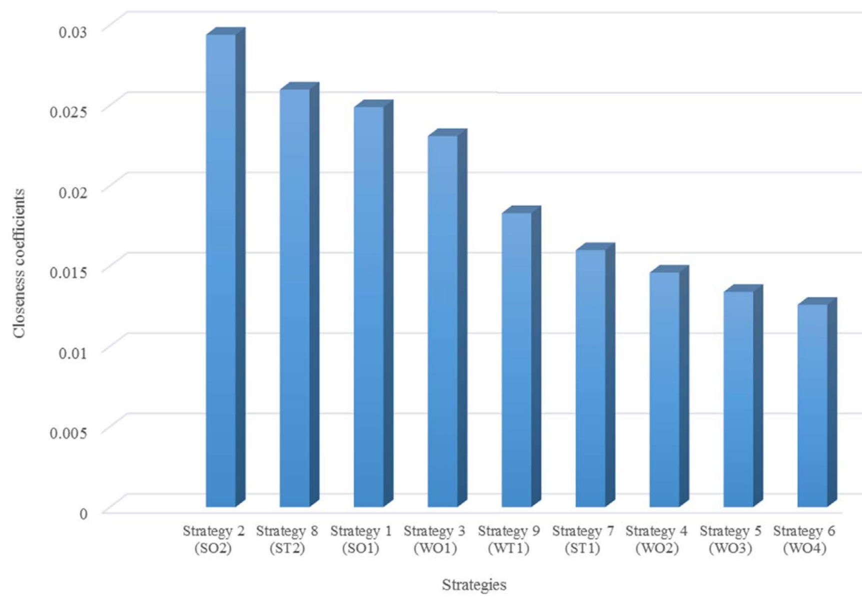

Fig. 5. Ranking graph of the strategies.

Table 12
SWOT factors weights according to different cases.

	Case 1 (current)	Case 2	Case 3	Case 4	Case 5
S	0.35	0.25	0.20	0.15	0.10
W	0.16	0.25	0.30	0.35	0.40
O	0.33	0.25	0.20	0.15	0.10
T	0.16	0.25	0.30	0.35	0.40

Table 13
Results of the sensitivity analysis.

Strategies	Case 1	Case 2	Case 3	Case 4	Case 5
Strategy 1 (SO1)	3	3	3	4	4
Strategy 2 (SO2)	1	1	1	1	1
Strategy 3 (WO1)	4	4	4	3	2
Strategy 4 (WO2)	7	7	7	7	7
Strategy 5 (WO3)	8	8	8	8	8
Strategy 6 (WO4)	9	9	9	9	9
Strategy 7 (ST1)	6	6	6	6	6
Strategy 8 (ST2)	2	2	2	2	3
Strategy 9 (WT1)	5	5	5	5	5

Middle Eastern and Central Asian energy/resource production to the world/European markets.

Second, third and fourth strategies, which are minimizing the negative environmental impacts of the activities in the energy area (ST2), increasing the share of the renewable energy resources within the energy supply (SO1) and increasing energy efficiency (WO1) closely relates to each other. In other words, they all supports one another. As stated in Vision 2023 policy, increasing the usage of renewable energy resources, the use of clean coal combustion technologies, and improvement of energy efficiency contribute to the conservation of the environment. Renewable energy sources take place as the second-largest domestic energy source after coal. In this respect, renewable energy sources seem to be one of the most efficient and the most prominent alternatives for clean and sustainable energy development in Turkey. It is important effectively tackle with theft and losses while electricity distributed on the line networks in order to increase energy efficiency.

The next strategy in the final ranking of the strategies is about increasing R & D activities in the energy area (WT1). Utilizing high qualified equipment and advance technology investments decrease the inefficiencies of the energy system, and thus coordinated with energy planning/management effectively. This strategy contributes most other strategies. That is, it helps countries (like Turkey) not only to find/adopt the best energy practices developed by others, but also to invent and innovate new technologies in the energy area. The remaining strategies are about providing diversity in resources by giving priority to the domestic resources (ST1), making the free market conditions operate fully and providing for the improvement of the investment environment (WO2), providing the diversity of resources in the area of oil and natural gas and taking the measures for reducing the risks due to importation (WO3), and using the nuclear energy technologies within the energy supply (WO4), respectively.

One of the remarkable point in the results is that using the nuclear energy technologies within the energy supply (WO4) strategy has the lowest priority rank among all strategies. In real, nuclear fuel is inexpensive and it is easy to transport. Although there are no emissions, or greenhouse gases that contribute to global warming, it nevertheless carries significant risks for both human health and the environment. Also, the nuclear disaster occurred in Japan showed the reality about the level of risks that a country is taking by having nuclear energy sources (i.e., reactors). This recent event may have an impact on the experts' opinions/perceptions and hence on the final ranking of the alternative strategies. For this reason, in this study, renewable and other clean energy sources and technologies outranked the nuclear energy option.

The Vision 2023 policy states that progress in the areas of energy supply security, the regional and global effectiveness of the country in the field of energy, environmental impact, and natural resources are important. These topics are all considered (among others) to identify and examined strategies/alternatives in the proposed model, and they all seem to complement each other under Turkey's energy policy framework. However, it should be stated here again that the aim of this study is not to make preferences among stated alternative energy strategies, rather, the study aims at determining and prioritizing alternative energy strategies for Turkey in a collective and holistic manner.

For future research, other fuzzy MCDM methods such as PROMETHEE, ELECTREE and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) can be applied to this problem and the results can be compared with the proposed ANP weighted fuzzy TOPSIS approach. Also, the results are specific to Turkey and its specific geo-political features/characteristics. It would be interesting to create other studies in other part of the world (both on developing and developed countries) and conduct a comparative analysis between these findings and the finding that can be obtained from those studies. As a future research direction, the study can be conducted to evaluate or plan the energy issues of Turkey for a period of time with respect to sustainability (and other issues as they relate to energy planning) as well as to verify the proposed framework. Based on the collective knowledge and data/information (mostly obtained from current databases, today's energy domain experts, and policy makers in Turkey), the movement behind renewable and sustainable energy is a relatively new focus for Turkey's strategic energy planning. Having dependent on foreign oil and gas for many decades for energy production (which is still the case, although not as dramatic), the new generation of decision makers are keen on exploring the potential for new alternatives (since Turkey seem to be one of those countries that has the good fortune of an ample amount of renewable/sustainable/green energy opportunities such as wind, solar, hydro, etc.) and by doing so, potentially easing the economic pain/dependence to outside sources while also improving the environmental impact.

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