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Research Article

A Multi-Criteria Decision-Making Approach for Sustainable Energy Prioritization

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Abstract
Iran's economy is highly dependent on energy exports and applying renewable energy (RE) resources is vital to optimize consumption function. The country has a high potential of REs, however, they have been long neglected because of several reasons including abundant natural gas and oil reserves. This study introduces and evaluates main plausible RE resources for the future of sustainable development in Iran. The goal is to investigate and rank Iran's main RE sources (biomass, geothermal, hydropower, solar PV, and wind). Criteria like technical, economic, environmental, and social are identified and subsequently used for evaluations. A new hybrid MCDM model based on analytic hierarchy process (AHP) and combined compromise solution (CoCoSo) methods is adopted to identify and select the main RE resource. The results indicate that solar PV possess the highest priority, while the economic criterion is the most effective to be considered. The results can help the decision-makers in the field of energy for more accurate planning and strategic management.
Keywords: Renewable energy, Sustainable development, Analytic hierarchy process, Combined compromise solution method, Multiple-criteria decision-making

Introduction

Sustainable development (SD) comprises a thorough and integrated way to the economic, social and environmentally functions (Karakosta & Askounis, 2010). A sustainable development approach seeks to provide services that meet the present basic human needs, in a cleaner and more efficient way without compromising the needs of future generations (Asgharizadeh et al., 2019). Nowadays, energy has a large environmental impact and it's undoubtedly very important for attaining the SD and the prosperity of a community (Naderi et al., 2020; Rezaei et al., 2020b). Increment in the energy efficiency of processes applying sustainable resources can very help in achieving sustainable development (Hepbasli, 2008). SD strongly recommends the use of energy sources that emit the least pollutants to the environment (Razmi et al., 2020). There is a need to developing new energy resources to replace or reduce the use of nonrenewable energy resources (such as coal, petroleum, natural gas, etc.) (Li et al., 2009).

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Renewable energy (RE) is one of the potential solutions for climate change, energy security and sustainable growth (Swain & Karimu, 2020). REs are produced applying harmless techniques that have less harmful impact on the environment in contrast to other kinds of energy (Chaharsooghi et al., 2015). So, renewable energy sources seem to be an effective solution for achieving sustainable development (Chaharsooghi & Rezaei, 2016; Rezaei et al., 2013). Considering the depletion of fossil fuels and the environmental problems caused by them, the use of renewable energy is crucial and it is predicted that the use of renewable energy will play a vibrant role in the world's energy portfolio (Makkiabadi et al., 2020). Many countries established legal framework to encourage applying RE resources (Behboudi et al., 2017).

Renewable or the so-called "green energy" like wind, solar, geothermal, and hydropower is inexhaustible, clean and free (Gökçek et al., 2007). The worldwide share of RE are not significant (18% of global energy consumption) (see Figure 1); still, its growth rate is anticipated to rise at a faster pace in all future scenarios. Figure 2 shows the global deployment potential of various RE resources in final energy consumption by 2050. As shown in this figure, the share of bioenergy and wind energy are higher than other resources (Gielen et al., 2019).

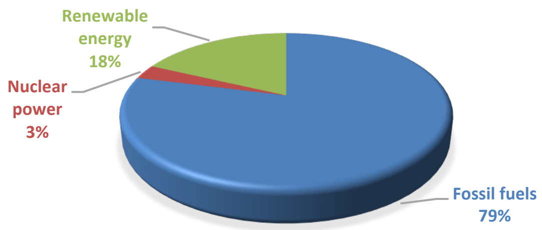

Figure 1. Energy consumption worldwide (Pereira et al., 2012)

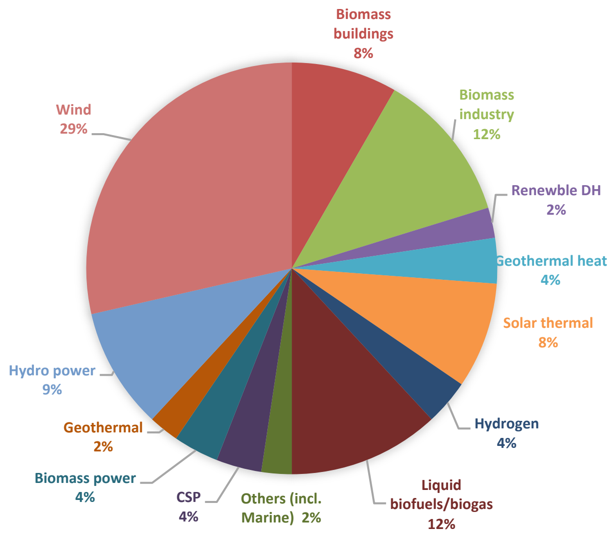

Figure 2. Global deployment potential of various RE resources in final energy consumption, 2050 (Gielen et al., 2019)

Iran holds the world's fourth-largest proved crude oil reserves (10% of the world's crude oil reserves) and the world's second-largest natural gas reserves (17% of the world's natural gas reserves). Iran's economy is highly dependent on the exports of energies, in which the major of Iran's exports are natural gas and oil.

Furthermore, thanks to its geographical situation, Iran has a high potential of renewable resources like wind, solar, geothermal, and biomass (Rezaei et al., 2020a). Unfortunately, due to having abundant natural gas and oil reserves, the development of these energies has been long neglected. Figure 3 shows the share of renewables in Iran's primary consumption. The share of REs in Iran's energy supply is very low (Solaymani, 2021). Currently, all forms of renewables receive attention from the government, less in some cases, and more in a few ones. Some types, like fuel cell hydrogen, despite large funding allocation have yet to show marked sign of progress and is not expected to reach to the commercializing phase in the near future. There are also other types of REs capable of providing energy security in Iran, but are strongly in need of more incentives and continuous support from the host state (Abbaszadeh et al., 2013). The most important reasons for the lack of proper development of renewable energy in the country are poor operational planning, multiple documents and offices of RE, and lack of proper use of the private sector (Norouzi et al., 2021).

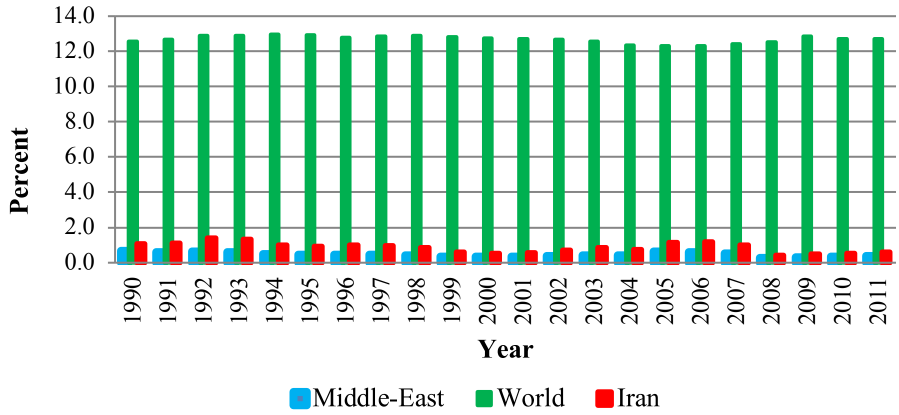

Figure 3. Share of renewables in primary consumption

There have been discussions in the scientific community over the past years in Iran on prioritizing funding allocation and apportionment for each REs, indicating adverse views on the five main RE resources (solar, biomass, hydropower, wind, and geothermal). So, this study tries to address this issue in hopes of a more proper decision making and avoiding knee-jerk policies. In this study a new hybrid MCDM method is proposed to rank Iran's RE sources. Analytic hierarchy process (AHP) as one of the most commonly MCDM method is adopted to identify key drivers in RE development in Iran and to weight the criteria and sub-criteria. Also to select and prioritize RE resources in the country Combined compromise solution (CoCoSo) method is applied. Moreover, it aims to analyze the issues posed by the multifaceted challenge of the energy transition of Iran.
The Structure of this paper is as follows:

Literature review

Decision-making in the field of environment is very difficult and complex. Due to the existence of various and often contradictory criteria in this field, in recent years, in many studies, multi-criteria decision making approach has been used for planning and prioritization (Ahmadipari et al., 2020; Farajollahi et al., 2018; Haghparast et al., 2020; Khalili et al., 2017). For Example, Padash (2017) used MCDM methods to model the environmental impact assessment for desalination and operating units. Similarly, energy planning has always been a challenge among policy makers with several parameters involved in decision making. Energy planning consists of selecting, prioritizing, and many other aspects of decision making needs various options, criteria, and other variables to be considered. MCDM as one of the approaches in this regard has always been popular in assessing different angles of energy planning. Many studies have utilized MCDM methods for their research to investigate the present or the future of energy status in both regional and national level (Begić & Afgan, 2007; Patlitzianas et al., 2007, 2008). Using MCDM, prioritizing alternative options like energy, technology, and scenarios have been promoted as a heavily attraction for decision makers. Several studies explored options of energy at either regional or national level using MCDM methods (Amer & Daim, 2011; Atmaca & Basar, 2012; Ö. Kabak et al., 2013). Some studies have tried to applied MCDM methods to determine the best energy scenario (Baležentis & Streimikiene, 2017; Ren et al., 2021; Tang et al., 2021). Hussain Mirjat *et al.* (2018) developed four scenario options in energy modeling effort. They applied AHP method to select the most appropriate electricity generation scenario. Höfer and Madlener (2020) used an MCDM method for evaluating the energy transition scenarios while considering the stakeholder opinions. They applied clustering method to derive the policy recommendations of sustainable energy transition. Some researches concentrated on assessing technology options by MCDM methods (Ghasempour et al., 2019; Ligus & Peternek, 2018; Siksnelyte-Butkiene et al., 2020).

Serrato *et al.* (2020) applied MCDM methods to compare ocean energy technologies of Colombia. They used economic, technical, and environmental criteria for accessing the alternatives. Shahnazari et al. (2020) used AHP and TOPSIS methods to choose the best energy recovery technologies from MSW considering the technical, financial, and environmental criteria. Some studies have used MCDM approach to select the best suitable locations for installation of power plants. For example, Jahangiri et al. (2020) used a fuzzy MCDM method to select the appropriate locations in Qatar to exploit solar and wind energy for generating electricity and hydrogen. Ghobadi & Ahmadipari (2018) used Fuzzy AHP and PROMETHEE methods in a GIS environment to select the best locations to establish wind power plants in Lorestan (a province in Iran). Saraswat et al. (2021) applied a model based on MCDM and GIS techniques for Investigating the best lactations to install wind and solar farms in India.

Researchers evaluate options with different criteria in their studies. Laes (2006) analyzed the justification of technological choices and options in the context of nuclear energy policy. Afgan and Carvalho (2008) used economic, environment, and social indicator for sustainability assessment method for evaluating the quality of the hybrid energy systems. Jing et al., (2012) proposed a model, that integrates the fuzzy theory and MCDM process, for assessing the comprehensive advantages of combined cooling, heating and power systems. Criteria such as technology, economic, society and environment were considered in this research. Some researchers assess different sources of energies like fossil fuels and nuclear energy. For instance, Önüt et al. (2008) utilized ANP method to probe the most suitable energy resources for the manufacturing industry. Energies such as fuel-oil, coal, electricity, LPG and NG were taken into account.

With heightened awareness of RE importance, new studies have more focused on this type of energy. A few researches have included RE along with primary energy in their exploration. Kabak et al. (2013) for instance, proposed a method based on a Cumulative Belief Degree (CBD) approach for ranking of energy sources in Turkey. Oil, Coal and lignite, Natural gas, nuclear, and five RE types were included in selecting the best option. They resulted that solar power and wind should be taken into account as the priori sources of energy in Turkey. Saraswat and Digalwar (2020) used fuzzy MCDM methods to evaluate energy sources in India. They considered sustainable factors to select the best energy sources (solar, thermal, nuclear, gas, wind, hydropower, and biomass). There are other studies where the focus were on only RE resources. They focused on RE with respect to different criteria. Baris and Kucukali (2012) evaluated the RE resource technologies in Turkey and found that the most appropriate RE alternative is biomass, simply because of the highest social benefit among others. Doukas et al. (2010) presented a method using TOPSIS and fuzzy method to appraise the RE Sources options' contribution to Sustainable Development (SD). Abdel-Basset *et al.*, (2021) used fuzzy MCDM methods to select the best renewable energy sources in Egypt under uncertain environments. The results of this study showed that solar was the most appropriate source of RE for Egypt.

In most RE evaluations, two or three criteria form technical, economic, environmental and social aspects were considered. Aras et al. (2004) focused on technical and economic parameters, and concentration of Nigim et al., (2004) were on technical, economic, and environmental aspects. It has also been revealed that most of the studies in RE sector applied traditional evaluation methods, including techno-economic assessment or cost−benefit analysis (Amer & Daim, 2011). In this research, all four main criteria and the most important sub-criteria involved in investigation and evaluation of different sources of energies are included, as it is vital to have a comprehensive decision making in the field of energy. In addition, a new hybrid MCDM method is proposed for ranking the alternatives. The proposed approach is applied in a real case study to prioritize Iran's RE sources.

Renewable energy in Iran

This section brings a brief current status of the five main REs (biomass, geothermal, solar PV, hydropower, and wind) in Iran. Due to the geographical location of Iran, there is the greatest potential for the production of renewable energy from these sources and other renewable energies have a very small share in Iran's energy basket. Presently, fuel cell hydrogen is in the pre-commercial phase in Iran and is not expected to have a notable effect on energy sector until the medium term (Nasiri et al., 2015). Thus, for a more appropriate evaluation, this technology is not included in the assessment.

Biomass: Iran has a high potential for biomass because of its great generation of agricultural, animal and municipal waste (Ardebili et al., 2011). Share of biomass waste potential energy in Iran in Figure 4. In 2009, the country has established two biomass power plants in some cities including Shiraz and Mashhad, to generate biogas from the municipal garbage. The capacity of Mashhad's power plant is 4875 MWh, with nominal power of 600 kW and the Shiraz's capacity is 7455 MWh annually, with nominal power of 1200 kW. Netherlands, Germany, and Spain helped Iran for establishing the above power plants.

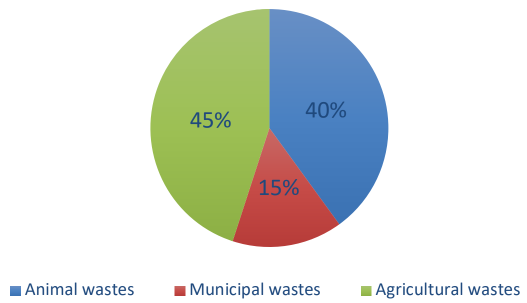

Figure 4. Share of biomass waste potential energy in Iran (Hamzeh et al., 2011)

Geothermal: Iran is located on the global geothermal belt and is considered among the prevalent countries having geothermal energy (Atabi, 2004). Figure 5 shows the Iran's potential areas of geothermal resources which are ranked in order of importance. As shown in Figure 5 the north and Northern provinces have substantial potentials. There are several hot water springs in these regions, in which the temperature of some of them reaches till 85 °C (Ghobadian et al., 2009).

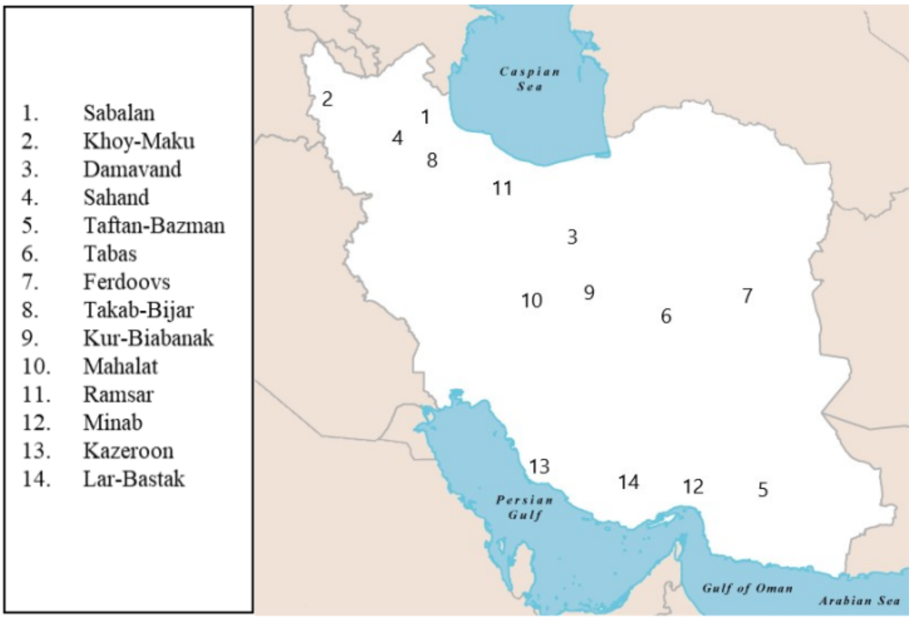

Figure 5. Geothermal potential areas in Iran (Hosseini et al., 2021)

Solar: Iran also has a high capability in other types of renewable energies. For instance, Iran's solar atlas is among the best of the world. 60% of Iran's area consists of wastelands that offer high solar radiations. The Iran's solar energy varies from 2.8 kWh/m2 in day in the north to 5.4 kWh/m2 in day in the south. Because of having sunny days and sun rays in most days, central, eastern, and southern provinces are capable of being self-sufficient to provide their needed energy from their own regions.

Wind: Iran has also high potentials to exploit wind power. Thanks to mountains and coasts including Persian Gulf Coast, Iran is capable of exploiting this type of energy in wide-scale. In addition, the country possesses various tropical wind flows such as the western flow from Atlantic Ocean and Mediterranean Sea in winters and the north western flow in summers; and the flow from Central Asia during winters and Indian Ocean during summers, (Ghorashi & Rahimi, 2011). In recent years various regions that are suitable for installation of wind turbines have been spotted by the experts.

Hydropower: Nearly 2700 villages of Iran have water potential in suitable inclined plans by a radius of 10 km near them. The western, northern, and central regions of the country have the greatest potential for hydropower generation (Ghadimi et al., 2011). The amount of electricity produced by hydropower plants in the country during 2004 to 2016 is shown in Figure 6. According to this figure, an average of 12.84 TWh of electricity has been generated by this source over these years.

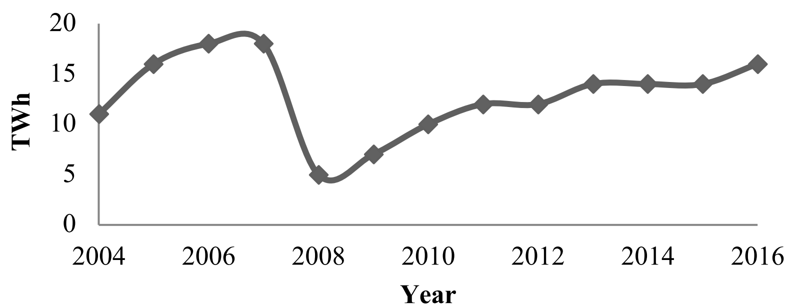

Figure 6. Electricity generation by hydropower plants in Iran

Description of criteria

Four criteria with thirteen sub-criteria are identified that have the most significant impact on the development of sustainable energies in Iran. The selected criteria and sub-criteria applied for evaluating different RE resources are listed in Table 1. The definitions of these criteria are as follows:

Table 1. Criteria and sub-criteria used for decision making.

Criteria	Sub-criteria	Studies (After 2007)
Technical	Efficiency	(Atmaca & Basar, 2012; Baris & Kucukali, 2012; Talinli et al., 2010; J.-J. Wang et al., 2009)
	Maturity	(Jing et al., 2012; Kahraman & Kaya, 2010; J.-J. Wang et al., 2009)
	Reliability	(Baris & Kucukali, 2012; Kahraman & Kaya, 2010; J.-J. Wang et al., 2009)
	Resource availability	(Amer & Daim, 2011; Atmaca & Basar, 2012; B. Wang et al., 2010)
	Expert Human Resource	(Kahraman et al., 2009; Lee et al., 2008)
Economic	Investment cost	(Baris & Kucukali, 2012; Doukas et al., 2010; Jing et al., 2012; J.-J. Wang et al., 2009)
	O&M cost	(Amer & Daim, 2011; Atmaca & Basar, 2012; Phdungsilp, 2010; J.-J. Wang et al., 2009)
	Availability of funds	(Kahraman et al., 2009; Kahraman & Kaya, 2010)
	Electric cost	(J.-J. Wang et al., 2009)
Environmental	Land use	(Jing et al., 2012; Ruan et al., 2010; B. Wang et al., 2010; J.-J. Wang et al., 2009)
	Emissions (greenhouse gasses etc.)	(Chatzimouratidis & Pilavachi, 2007; Lee et al., 2008; J.-J. Wang et al., 2009)
Social	Job opportunities	(Amer & Daim, 2011; Atmaca & Basar, 2012; Baris & Kucukali, 2012; Phdungsilp, 2010; B. Wang et al., 2010)
	Social benefits	(Amer & Daim, 2011; J.-J. Wang et al., 2009)

Technical

"Efficiency" represents the amount of useful energy that is obtained from a source. The ratio of the output energy to the input energy is defined as "efficiency coefficient". This is the most used technological criteria in studies evaluating energy systems (J.-J. Wang et al., 2009). "Technical maturity" is a criterion to assess the applied energy systems technologies (J.-J. Wang et al., 2008). It also takes into account the improvement phase of the technology; i.e., whether the technology has the potential to improve, or if it has reached its theoretical limit (Amer & Daim, 2011).

"Reliability" is determined as the ability and also capacity of a system to perform as intended under certain conditions, for a stated time period (Amer & Daim, 2011). Several factors and events are increasing the concerns about energy reliability, including great profile terrorist activity, political tensions, and massive blackouts (McCarthy et al., 2007). "Resource availability" implies to the availability of renewable energy resources (solar radiations, wind speed, etc.) for energy production. Some indicators of availability are accessible and proven reserves of the energy source, and ready technologies for accessing the energy sources (P. Gerdsri, 2009). "Expert Human Resource" is another parameter for technical criterion for the availability of expert man power in the area for installing, operating and maintaining the equipment.

Economic

"Investment cost" is the most popular economic parameter to assess energy systems. The components of the investment cost are the procurement and installation of technical equipments, the construction of roads and connections to the national grid, engineering services, drilling, and other incidental construction works. "Operations and maintenance cost" consists of staff fee, production expenditure, and service costs. Fixed and variable costs are the two sub-categories of the operation and maintenance costs. "Availability of funds" criterion asseses the national and international sources of funds and government supports (Kahraman et al., 2009). "Electric cost" refers to the expected cost of the electricity generated by power plant. Governments, investors, producers and consumers have different expectation on this criterion. It's necessary to assess the electric cost of different energy systems rationally (J.-J. Wang et al., 2009).

Environmental

Power plants occupy lands, which can affect the landscape and increase the project costs. As the lands required for energy projects increase, "Land use" criterion becomes a great concern for their evaluation (Kaya & Kahraman, 2011). It's a critical factors for the intervention site, especially where the activities of humans are relevant factors of environmental pressure (Beccali et al., 2003). "Emissions (greenhouse gasses etc.)" evaluates the impacts of emissions released by operations of the power plants -including greenhouse gasses, small particles etc.-on public health.

Social

New energy projects usually make "employment opportunities" and new professional figures, particularly for local communities (Kahraman & Kaya, 2010). Energy supply system employs much people during their life cycle, from construction and operation until decommissioning (J.-J. Wang et al., 2009). A "social benefit" shows the social progress in the local society and region, through initiating an energy project (Amer & Daim, 2011). Some items such as Social life and income generation can be considered as the scopes of this criterion.

Methodology

The world around us is full of multi-criteria issues, and humans are always forced to make decisions in these situations. In addition, in most cases, these criteria are contradictory and the decision-making process is very difficult. In this regard, the multi-criteria decision-making methods help the decision makers to select the best alternative under the presence of multiple criteria.

The multi-criteria decision-making (MCDM) methods are categorized into two groups: multiple-attribute decision-making (MADM) and multiple-objective decision-making (MODM) methods (Hwang & Yoon, 2012). MADM methods are used to select an alternative from a small size set of discrete actions, while MODM methods are used to choose an alternative from a large set of alternatives implicitly defined by some constraints (Goyal & Kaushal, 2018). In this study, a new hybrid MCDM model by combining AHP and CoCoSo methods is proposed. The descriptions of these methods are stated in the following.

Analytic hierarchy process (AHP)

The analytic hierarchy process (AHP), introduced by Satty (Satty, 1980), is a simple, mathematically based multi-criteria decision-making tool that helps the decision makers to organize a complex problem into a hierarchical structure for analyzing relationships pertaining to a goal, objectives, and alternatives. AHP is a widely used discipline that has been applied successfully in various areas such as energy systems (Taylan et al., 2020), business decisions (Cadena et al., 2020), public policy (Hassan & Lee, 2019), heath care (Yzeiri & Baki, 2017) and etc.. It's a flexible method which can accurately convert human judgment to numerical scores in decision-making processes (Forman & Gass, 2001). It also enables the decision makers (DM) to consider both qualitative and quantitative judgments into a decision-making problem (N. Gerdsri & Kocaoglu, 2007).

Several studies investigated the effectiveness of AHP compared with other MCDM methods. For instance, Ghotb and Warren compare AHP and Fuzzy Decision Analysis in a medical arena (Ghotb & Warren, 1995). Their study results show that in the case of limited uncertainties, it is wiser to use AHP. Or in a study focused on the mathematical relationship between AHP and the Non-Traditional Capital Investment Criteria (NCIC) approach in a business arena, Boucher and Gogus concluded that AHP has a superior ability in measuring and controling consistency of judgments using both pair-wise and eigenvector comparisons (Boucher et al., 1997). In short, AHP can be adopted in several types of MCDM problems and despite the method takes more time than other models, results are more accurate and closer to what decision makers think. In this literature, AHP can be appropriately applied as there are some criteria and options involved. A few studies have already successfully adopted AHP for decision-making in energy field (Hussain, 2019; Konstantinos et al., 2019). Therefore, the technique can be a good fit in the case of prioritizing renewable resources.

Pairwise comparisons are applied to rate criteria and options. The relative importance recommended by Saaty is listed in Table 2. Contrary to Saaty, Kocaoglu suggested constant sum approach by allocating 100 points between each pair instead of 1-9 scale (Kocaoglu, 1983). The constant sum method (using 100 points) is believed to be more efficient than 1–9 scale measurement approach (P. Gerdsri, 2009) and therefore, this scale is adopted here in estimating the impact of criteria.

Table 2 The AHP pair-wise comparison scale (Saaty, 1977)

Intensity of weight	Definition	Explanation
1	Equal importance	Two criteria contribute equally to objectives
3	Weak/moderate importance	Experience and judgment slightly favored one criteria over another
5	Strong or essential importance	Experience and judgment strongly favor one criteria over another
7	Very strong importance	A criterion is favored very strongly over another
9	Absolute importance	The evidence favoring one criteria over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	These values can be used to represent intermediate values

Combined compromise solution (CoCoSo) method

CoCoSo is a new multi-attribute decision-making method that presented by Yazdani et al. (2018). This is a combined compromise decision-making method that originates from some famous methods like WASPAS and GRA.

The steps of the CoCoSo method are presented as follows:

Step 1- Construct the initial decision-making matrix, shown as follows:

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}, i \in \{1, 2, \dots, m\};\ j \in \{1, 2, \dots, n\}. \quad (1)$$

Step 2- Calculate the normalized decision matrix according to compromise normalization equation (Zeleny, 1973):

$$r_{ij} = \begin{cases} \dfrac{x_{ij} - \min\limits_i x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}}; & j \in \Omega_{max} \\ \dfrac{\max\limits_i x_{ij} - x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}}; & j \in \Omega_{min} \end{cases} \quad (2)$$

Where Ω_{max} and Ω_{min} represent the sets of benefit and cost criteria, respectively.
Step 3- Calculate the sum of the weighted comparability sequence for each alternative (Equation 3).

$$S_i = \sum_{j=1}^{n} (w_j r_{ij}) \quad (3)$$

Similarly, calculate the sum of the power weight of comparability sequences for each alternative (Equation 4).

$$P_i = \sum_{j=1}^{n} (r_{ij})^{w_j} \quad (4)$$

Step 4- Three appraisal score strategies are proposed to calculate the relative weights of the alternatives (Equation 5-7).

$$k_{ia} = \frac{S_i + P_i}{\sum_{i=1}^{m} (S_i + P_i)} \quad (5)$$

$$k_{ib} = \frac{S_i}{\min\limits_i S_i} + \frac{P_i}{\min\limits_i P_i} \quad (6)$$

$$k_{ic} = \frac{\lambda(S_i) + (1 - \lambda)(P_i)}{\lambda \max\limits_i S_i + (1 - \lambda) \max\limits_i P_i}; \quad 0 \leq \lambda \leq 1 \quad (7)$$

Where in Equation 7, λ is chosen by decision-makers (usually λ is equal to 0.5).
Step 5- Calculate k_i for all the alternatives (Equation 8). Rank the alternatives based on the decreasing values of $k_i's$.

$$k_i = \sqrt[3]{k_{ia}k_{ib}k_{ic}} + \frac{k_{ia} + k_{ib} + k_{ic}}{3} \quad (8)$$

Results and discussion

In this study a new hybrid MCDM model by combining AHP and CoCoSo is proposed to rank Iran's RE sources. First AHP method is applied to weight the criteria. Then, CoCoSo method is used to rank the alternatives.

The AHP model is shown in Figure 7. The model is composed of three level comparisons: goal, criteria, and sub criteria. The sub-criteria level is applied for better appraisal of each criterion.

To identify the significance of each parameter, criteria, and sub-criteria are compared with each other. Experts' subjective judgments are then used for pairwise comparison, which subsequently, weight of criteria, and sub-criteria are obtained.

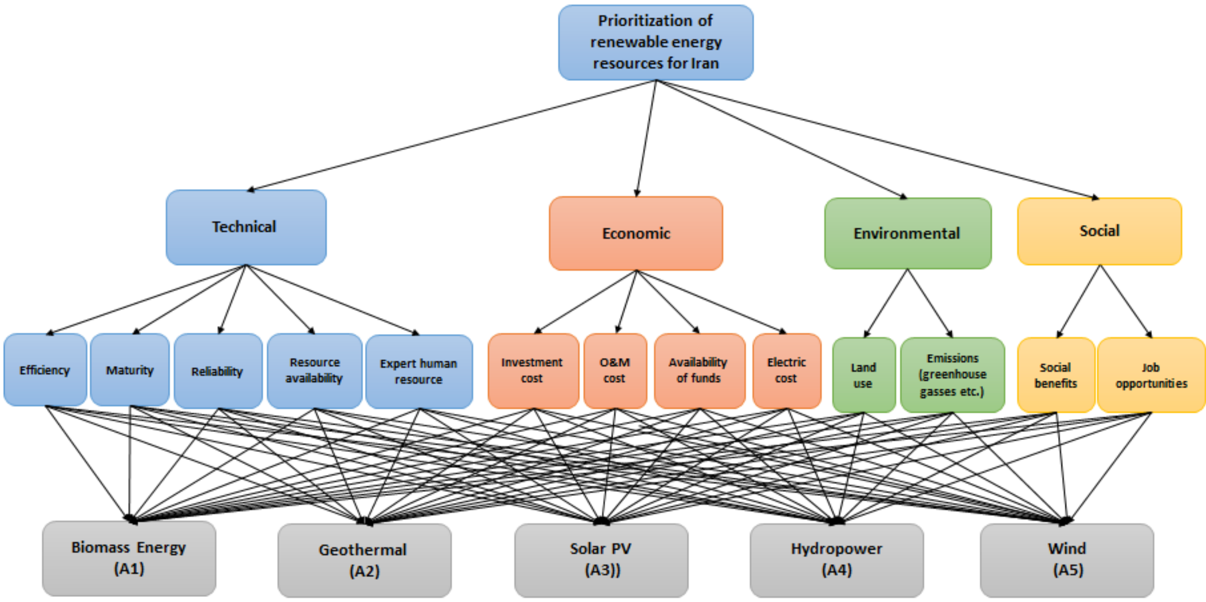

Figure 7. AHP structure.

A survey was developed for acquiring subjective judgments from experts. They were asked to make pairwise comparisons of the criteria with respect to the goal and sub-criteria with respect to each criterion. Using constant sum method (100 points), experts were asked to express their judgment of one element versus another. In comparing two criteria, for instance, 60 points is for the technical criterion and 40 point is for the social criterion.

Tables 3 and 4 show the weights of criteria and sub-criteria that obtained by AHP method. As shown in Table 3, the economic criterion with relative weights of 0.565 has the highest value. This is thus the main parameter that the government should address in order to the energy transition. Technical criterion comes as the second with the weight of 0.262, and environmental aspect is found by experts to be the least important factor with the weight of only 0.055. Through the investigation of sub-criteria, it is revealed that reliability is the most important criterion for the technical aspect. Table 4 also represents that investment cost, land use, and job opportunities are the most consequential sub-criteria for the economic, environmental, and social benefits criteria respectively.

In this section, CoCoSo method is used to rank the alternatives. The criteria weights that obtained by AHP method is used as input parameters of CoCoSo method. The decision-making matrix values are obtained by the experts' opinions. After normalization of the decision matrix, sum of the weighted comparability sequence for each alternative is calculated (Table 5). Similarly, as shown in Table 6, sum of the power weight of comparability sequences is calculated by Equation 4.

Table 3. Relative weights of criteria.

Criteria	Weight
Technical	0.262
Economic	0.565
Environmental	0.055
Social	0.118

Table 4. Weights of sub-criteria.

Id	Sub-criteria	Relative impact
C1	Efficiency	0.076
C2	Maturity	0.137
C3	Reliability	0.369
C4	Resource availability	0.364
C5	Expert human resource	0.054
C6	Investment cost	0.441
C7	O&M cost	0.127
C8	Availability of funds	0.142
C9	Electric cost	0.289
C10	Land use	0.750
C11	Emissions (greenhouse gasses etc.)	0.250
C12	Job opportunities	0.750
C13	Social benefits	0.250

Table 5. Weighted comparability sequence

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	Si
Weights	0.076	0.137	0.369	0.364	0.054	0.441	0.127	0.142	0.289	0.75	0.25	0.75	0.25	
	max	max	max	max	max	min	min	max	min	min	min	max	max	
A1	0.063	0.000	0.079	0.182	0.018	0.000	0.051	0.000	0.193	0.167	0.000	0.563	0.000	1.315
A2	0.076	0.000	0.053	0.000	0.000	0.110	0.038	0.000	0.193	0.250	0.062	0.375	0.000	1.157
A3	0.000	0.069	0.369	0.364	0.036	0.441	0.013	0.114	0.289	0.750	0.250	0.750	0.250	3.694
A4	0.025	0.137	0.000	0.091	0.054	0.331	0.127	0.142	0.193	0.000	0.062	0.000	0.250	1.412
A5	0.076	0.000	0.316	0.182	0.036	0.221	0.000	0.028	0.000	0.417	0.188	0.000	0.000	1.463

Table 6. Power weight of comparability sequences

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	Pi
Weights	0.076	0.137	0.369	0.364	0.054	0.441	0.127	0.142	0.289	0.75	0.25	0.75	0.25	
	max	max	max	max	max	min	min	max	min	min	min	max	max	
A1	0.986	0.000	0.566	0.777	0.942	0.000	0.890	0.000	0.889	0.324	0.000	0.806	0.000	6.181
A2	1.000	0.000	0.488	0.000	0.000	0.543	0.858	0.000	0.889	0.439	0.707	0.595	0.000	5.518
A3	0.000	0.909	1.000	1.000	0.978	1.000	0.746	0.969	1.000	1.000	1.000	1.000	1.000	11.603
A4	0.920	1.000	0.000	0.604	1.000	0.881	1.000	1.000	0.889	0.000	0.707	0.000	1.000	9.001
A5	1.000	0.000	0.945	0.777	0.978	0.737	0.000	0.796	0.000	0.643	0.931	0.000	0.000	6.806

In this step the values of k_a, k_b, and k_c are calculated by Equations 5-7. Then, the values of k are calculated by Equation 8 (Table 7). The ranks of alternatives are based on the decreasing values of k. As is shown in Table 7, the results demonstrate that solar PV is the most preferable energy option for Iran.

Table 7. Ranks of the alternatives

	ka	Ranks	kb	Ranks	kc	Ranks	k	Ranks
A1	0.156	4	2.256	4	0.490	4	1.524	4
A2	0.139	5	2.000	5	0.436	5	1.353	5
A3	0.318	1	5.295	1	1.000	1	3.393	1
A4	0.216	2	2.851	2	0.681	2	1.998	2
A5	0.172	3	2.498	3	0.541	3	1.685	3

A comparison between the results of this study and other studies is shown in Table 8. According to Table 8, the AHP-CoCoSo method has not been used so far. Also, in this research, in addition to technical criteria, all dimensions of sustainable development (economic, environmental and social) have been considered. As shown in Table 8, different prioritization results have been obtained in different studies. Various reasons for this difference in the results can be stated:

- The criteria used in these studies to evaluate renewable energy sources were different.
- Evaluations are based on the geographical characteristics and the potential of each country in relation to renewable energy.
- Because different MCDM methods have been used, and since these methods have different algorithms, different results have been obtained.

Table 8. Comparison of various studies in the prioritization of renewable energy sources

References	Country	Method	Best resource
(Nigim et al., 2004)	Canada	AHP & SIMUS	Solar
(Amer & Daim, 2011)	Pakistan	AHP	Biomass
(M. Kabak & Dağdeviren, 2014)	Turkey	ANP	Hydro power
(Ishfaq et al., 2018)	Pakistan	AHP-VIKOR & AHP-TOPSIS	Hydel power
(Abdel-Basset et al., 2021)	Egypt	AHP-VIKOR & AHP-TOPSIS	Solar
This study	Iran	AHP-CoCoSo	Solar

In order to validate the results, the proposed method is compared with TOPSIS method, which is one of the typical MCDM methods. It should be noted that for the weights of the criteria, the results of the AHP method have been used. In the TOPSIS method, first the normalized decision matrix must be obtained and then the weighted normalized decision matrix must be calculated.

In the next step, the distance from the ideal best (d_{ib}) and the distance from the ideal worst (d_{iw}) should be calculated and after calculating the closeness coefficient (cl_i), they should be ranked in descending order.

As shown in Table 9, the best option is solar energy. The result is in accordance with the result of AHP-CoCoSo method, which shows the accuracy of the proposed method. It should be noted that as previously described, the algorithms and steps of the methods are different, indicating that other differences in the results are logical.

Table 9. Ranks of the alternatives by TOPSIS method

	d_{ib}	d_{iw}	cl_i	Ranks
A1	3.133	1.824	0.368	4
A2	3.071	1.818	0.372	3
A3	0.454	4.295	0.904	1
A4	3.640	1.904	0.343	5
A5	2.569	2.465	0.490	2

Conclusion

This literature appraised and analyzed the five main RE resources in Iran that is estimated to play a more significant role in the future of Iran's energy sector. Various criteria can be defined to evaluate these renewable energies, which, in this study, in addition to technical criteria, all dimensions of sustainable development (economic, environmental and social) have been considered for a comprehensive evaluation of these resources. A new Hybrid MCDM model by combining AHP and CoCoSo methods proposed to prioritize and rank the most important RE resources in Iran. First by AHP method the weights of criteria were calculated. Then using CoCoSo method, the ranks of RE sources were obtained. Finally, the proposed method was compare with TOPSIS as a typical MCDM method.

Applying the method, it was determined that solar PV is the best option for sustainable energy development for Iran. It was also found that economic parameter is the most important factor that should be carefully taken into account. In addition, reliability, investment cost, land use, and job opportunities were the most consequential sub-criteria for the technical, economic, environmental, and social criteria, respectively.

The method accompanied by AHP-CoCoSo for the first time for the country would help policy makers and managers to have a better decision making. Investments can be allocated considering RE alternatives specified as well as criteria discussed in this paper. In this study, we have sought an efficient decision with a comprehensive view through considering all effective factors. This will prevent hasty policies from taking into account the wrong factors.

The country has a specific climatic condition with unique geopolitical and geographical features, and thus, no single alternative can be considered as an ideal solution for the whole country. However, a combination of multiple suitable technologies offers diversity, system redundancy, and long-term sustainable development. Development of renewable energies can help in reducing air pollution problem in big cities of Iran. It can also bring a unique opportunity for more exporting of fossil fuels and also energy security that can increase Iran's geopolitical position in the region. The AHP-CoCoSo model applied in this paper can further be used for the long-term national RE policy or assessing RE usage for major cities in Iran. Some suggestions for future research are as follows:

- Considering uncertainty and using fuzzy logic in the proposed model.
- Applying the proposed method in other countries.
- Applying other MCDM methods and comparing with the results of this research.
- Performing sensitivity analysis to evaluate the effect of the criteria on the results.

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