A SWOT-AHP Analysis of Renewable Energy Development Strategies in Iran

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A SWOT-AHP model is employed to investigate the strategies of the renewable energy development and the management solutions in Iran. The governing factors were assessed and evaluated in four weaknesses, strengths, opportunities, and threats (SWOT) groups. In addition, the negative and positive effects of internal and external factors were analyzed to bring out management strategies to develop the renewable energies. These strategies might be helpful in the protection of the environment and mitigate the impacts of climate change. Subsequently, the strategies were divided based on the most critical priorities by the analytic hierarchy process (AHP) model. The external matrix with the total score of 4.199 identified as the most critical opportunity factor of the renewable energy potentials in Iran. In addition, the results of the internal matrix with the total score of 4.866 were recognized as the main strength for the renewable energies development to generate electricity to reduce environmental pollution. According to the results, most important strategies included: increasing guaranteed electricity purchase tariffs (GEPTs) of renewable energies, establishment of the renewable energy fund and supply financial resources through shaping a competitive market for investors and suppliers and also increase financial security and electricity exporting, establishing and developing the infrastructures such as research, training, testing, certificating and standardizing centers of the renewable energy systems, and improving guaranteed electricity purchase contracts of renewable energies to encourage investors.

keywords: *Renewable Energy, SWOT, AHP, Greenhouse Gas, Sustainable Development*

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1. INTRODUCTION

The Utilization of renewable energy sources is one of the most essential factors in sustainable development [1, 2]. A selection of suitable energies is regarded as a significant economic factor in industrial societies because energy is a fundamental need for sustainable economic development, social welfare, improving the quality of life, and community security [3]. The concept of sustainable energy is realized if energy is produced and consumed to provide long-term human development in all economic, social, and environmental aspects [4]. Therefore, sustainable energy is essential for sustainable development. Thus it should be focused on renewable energies (such as: solar energy and wind energy, etc.) to diversify energy resources. Also, developing countries try to reduce their dependence on fossil energies, and the development of renewable energies, and pay attention to climate change[5]. The renewable energies plays the leading role in energy security, social, economic, and environmental issues [6]. The energy transition can improve the efficiency, affordability, and reliability of energy systems, by redefining and reclaiming citizens' participation in energy planning and policy-making [7]. Solar energy is the most significant potential for meeting the future demand of the world [8]. Because of geographic location, there are great potentials of solar, wind, geothermal, and biomass energies in Iran [9]. The potentials could be used if more investments were provided [10]. Technology transfer to developing countries is one of the goals of UN development in the field of environment. Therefore, the United Nations Convention on Climate Change (UNFCCC) tries to pave the way for cooperation among the developing and developed countries to achieve the goals such as promoting, facilitating and financing, and transferring or accessing environmentally friendly technologies or knowledge through providing coherent plans[11]. Accordingly, it was adopted at the 16th COP16 meeting in Cancun, Mexico, in 2010 with the aim to facilitate and improve the activities related to the technology development and transfer to support the mitigation and adaptation plans. It is worth noting that according to the provisions of paragraph 1 of the 16th commitments meetings, the executive technology committee and the

center for climate and network technology are required to facilitate the full implementation of the technology mechanism and promote coherence and synergy. In addition, the 21st summit (COP21) was held in December 2015 in Paris, and the fulfillment of the commitments of the Paris summit were emphasized at the end of 2018 in the 21st summit (COP24) in Poland, and the implementation of obligations was stipulated since 2020[12]. Due to the increasing contribution of developing countries in generating greenhouse gases (GHGs) and their impact on climate change, technology needs assessment (TNA) is a requirement for each country[13]. According to the second report of the second national Communication (SNC) by the Iranian environmental protection agency to the UNFCCC in 2010, Iran's energy sector emits 90% is predicted that the GHGs in the energy sector can be decreased by 69% compared to the consumption growth in the typical consumption scenario in 2050 through utilizing numerous renewable energy sources and capacities by implementing energy efficiency measures[14]. In the literature, several studies were done about the energy sector of Iran. The energy sector in Iran as the most significant contributor of anthropogenic emissions of GHGs was reviewed and applied to conduct a SWOT analysis to low carbon technologies by Talaei et al. and results of technology prioritization suggest that the transport, oil, gas, and electricity sectors are the highest priority sectors from technological needs perspective[15]. Mollahosseini et al.[9] presented a general review of the status of renewable energies and their potentials in Iran and comparisons of the current state, plans, and potential opportunities of Iran. This article focused on the potentials of Iranian renewable energies. Noorollahi et al. [16] developed a new optimization framework for the planning of the power generations with the inclusion of the renewable energy for Iran. Their results showed the increasing trend for renewable technologies shares, including the wind, solar, biomass, and geothermal energy. Zanjirchi et al.[17] developed modeling of the critical factors of success and failure to promote of solar energy in the form of a Business Model Canvas (BMC) and then extracted development scenarios on this basis. Ghorbani et al. [18] modeled three scenarios for transitions of Iran's power system from 2015 to 2050 by technical and economic analysis and presented a transition to 100% renewable energies at an optimal cost. Alizadeh et al. [19] introduced a framework to plan renewable energy resource use and make the decisions by a hybrid model including critical factors such as Benefit, Opportunity, Cost, Risk (BOCR), and Analytic Network Process (ANP) models. But all of these researches have not been a viewpoint of the management. Norouzi et al. have studied to prioritize the superiority on some technologies and select the suitable option for investing on renewable energies using the fuzzy logic algorithm and engineering economics in Qazvin province, Iran [20]. Also, we can review the recent researches as following. Oryani et al. [21] identified and ranked the main barriers to developing of the three alternatives in Iran, named solar PV, wind turbines, and biomass by analytical hierarchy process (AHP) method. They have identified and accordingly have grouped thirteen barriers into five dimensions, called: 1- Economic and financial, 2- Social, cultural, and behavioral, 3- Political and regulatory, 4. Technical, and 5. Institutional. Shorabeh et al. [22] assessed for establishing multi-renewable energy farms in an area. For this purpose, a series of environmental and economic criteria were addressed and investigated. Respectively, Analytical Network Process (ANP) and Fuzzy logic employed for obtaining the required weights as well as accounting for the element of uncertainty among the different criteria. The final suitability maps for identifying the most optimal locations for the institution of renewable energy farms obtained using Weighted Linear Combination (WLC) method. The potential assessment of multi-renewable energy farms establishment using spatial multi-criteria decision analysis: A case study and mapping in Iran. Sedghiyan et al. [23] applied multi-criteria decision analysis and concentrated using renewable resources in five climate zones in Iran, employing AHP, TOPSIS, and SAW methods. Solar, geothermal, hydropower, biomass, marine, and wind energies were reviewed in view of the primary renewable resources. The alternatives were prioritized from the technical, economic, energy security, and social points of view using different sub-criteria. The indicator weights were achieved through a survey of 100 academics and industrial experts whose research interests were energy and environmental science. The prioritization of renewable energies resources was done in five climate zones in Iran by using AHP, hybrid AHP-TOPSIS, and AHP-SAW methods. Jahangir et al. studied, analyzed and optimized a renewable-assisted multi-generation system in energy, exergy, and exergoeconomic[24]. In the literature, the articles of the renewable energy development of Iran were reviewed. But many of them are related to the potential analysis, technological, and economics challenges. However, the challenges of energy management are more critical in Iranian renewable energy issues, especially. Therefore, this research tries to present the management solutions regarding the present conditions in Iran and address to overcome these challenges by using a hybrid SWOT-AHP method as a new approach. As following, it is described the methodology, included the SWOT and AHP methods, in Section 2. Also, the Section 3 included results and discussion with four categories of ST, WT, WO, and SO strategies. Finally, the conclusion was presented in Section 4.

2. METHODOLOGY

The factors, which effect on the renewable energy development, were analyzed to identify the main parameters [25, 26]. Fig.1 shows the management plan which is applied hybrid SWOT matrix analysis and AHP method [27]-[30]. The SWOT management analysis includes four components: strengths and weaknesses, threats, and opportunities. The factors are surveyed on based the environmental characteristics and the management conditions.

A. SWOT-based evaluation

The SWOT analysis method is an analytical model. It systematically identifies the factors: strengths, weaknesses, opportunities, and threats as shown in Fig.2 [25]. In the SWOT model, each factor was assigned a weighting coefficient rates from 0 (not important) to 1 (very important) after identifying the external and internal factors. The sum of internal and external factors should equal one, and then the opinions of experts and managers should be used to determine the weight of each factor and decide on the high or low important factors. The score of current status ranges between 1-5, which the points were determined according to the current status of the organization and its environment. The weighted points were obtained by multiplying the weight obtained by the current status point. The desired strategies were derived from the intersection of external and internal factors. Therefore, this matrix always results in four categories of ST, WT, WO, and SO strategies. Comparing the external and internal factors and formulating the WT, SO, ST, and WO strategies were the most difficult parts of SWOT matrix preparation which require high judgment and analysis. There-

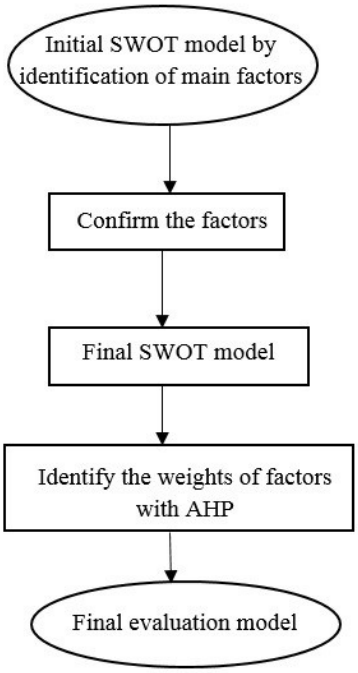

Fig. 1. A flowchart of the SWOT-AHP methodology

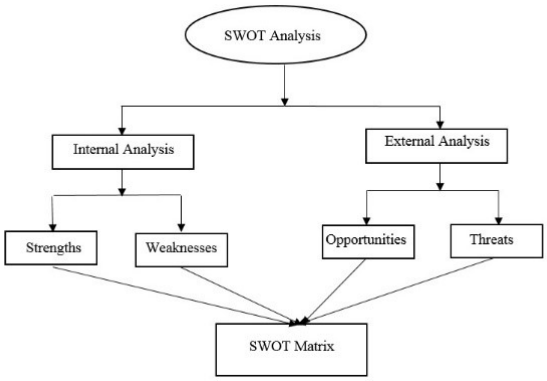

Fig. 2. SWOT Analysis

fore, a list of different strategies in four different groups was obtained through a SWOT matrix facing the developing and improving management conditions by focusing on environmental protection to mitigate climate change and the renewable energy development in Iran.

B. AHP method

The AHP method is a mathematical approach for searching and choosing the best plan from a set of possible plans. The decision tree hierarchies show the comparable factors and competing options evaluated in the decision [29] and [30]. Then, it is made a series of paired comparisons. These comparisons show the weight of each factor along with the competing options evaluated in the decision as follows in the four steps: In the first step, there are the objectives of the decision as a hierarchical set of interconnected decision elements. The decision elements included decision indicators and decision options. The AHP requires breaking a problem with several indicators into hierarchical levels. The high level represents the primary purpose of the decision-making process. The AHP requires breaking a problem with several indicators into a hierarchy of levels. The high level represents the primary purpose of the decision-making process. The second level represents the major indicators, which may break down to the more secondary and partial ones at the dimensional level. The last level presents the decision options. In the first step, there are the objectives of the decision as a hierarchical set of interconnected decision elements. The decision elements included decision indicators and decision options. The AHP requires breaking a problem with several indicators into hierarchical levels. The high level represents the primary purpose of the decision-making process. The AHP requires breaking a problem with several indicators into a hierarchy of levels. The high level represents the primary purpose of the decision-making process. The second level represents the major indicators, which may broke down to the more secondary and partial ones at the dimensional level. The last level presents the decision options. In the third step, the calculations needed to determine the propriety of each decision element through the pairwise comparison matrices data are applied in the AHP [31]. The total numbers are calculated by the matrix of the column of the pairwise comparisons, and then each entry of matrix is divided into the total number of that column. The numbers are calculated in each row by the normalized comparison matrix. The average of the numbers shows the relative weight of the decision elements with the matrix rows. In the fourth step, the relative weights of the criteria are integrated. In this step, the relative weight of each element multiplies in the weight of higher elements for obtaining the total weight to sort the decision options. The total weight is obtained by performing this step for each option. Comparing between the two options may be simple. However, it is not easy to ensure the compatibility of comparisons when the numbers increase to compare, and this confidence should be achieved by using the compatibility rate. The compatibility of the comparisons is acceptable when the incompatibility rate is less than 0.1. Otherwise, the comparisons should be revised[31], [32].

3. RESULTS

In the SWOT assessment, the strength points are higher if the total score of internal points is more than 2.5, and the weaknesses are higher if the total score is less than 2.5. Because the total score is 4.866, therefore there are some strengths for mitigating the impacts of climate change, as well as developing renewable energies related to internal factors. There are significant opportunities when the total score of external points in the SWOT evaluation is more than 2.5, and there are more threats when the total score is less than 2.5. Due to the total score of the external factors, which is 4.199, there are opportunities to mitigate the impacts of climate change and the development of renewable energies regarding the external factors.

Internal factors of the SWOT model:

S- Strengths:

S1: Great potentials for generating electricity from renewable energy sources.

S2: Saving fuel consumption.

S3: Reducing environmental pollutants, mainly emitting particulate matter.

S4: Activating the universities and research centers to localize

and expand the technical knowledge of renewable energy.
S5: Existing widespread lands to develop renewable energies.
S6: Reducing the GHG emissions.
S7: Distributed generation of electricity.
S8: Assisting the passive defense.
S9: Achieving the goals of the COP21 and its international affairs.
S10: Increasing synergies between renewable energy and high efficiency.
W- Weaknesses:
W1: Need relatively high investments, on the other hand, lack of government funding.
W2: No optimistic view among Iranian authorities to develop renewable energy.
W3: Not existing enough technical knowledge to fully design and manufacture the most needed elements, such as solar cells in Iran.
W4: Economical issues and especially subsidized fossil fuels prevent taking severe measures to develop renewable energies nationally.
W5: Not enough funding needed to performance new projects and not enough budgets for guaranteed electricity purchase tariffs (GEPTs).
W6: Political and economic instability for investment.
W7: Slow contracting procedures of investors, contractors, counsellors and managers.
External factors of the SWOT model:
O-Opportunities:
O1: high renewable energy resources for generating electrical power in Iran.
O2: Iran's membership in International Renewable Energy Agency and global positive approach to renewable energy usage.
O3: Job creation.
O4: Laws to encourage the private sector to invest in renewable energies by above-market price for producers (Feed-in Tariff).
O5: Establishing a support system for power purchase agreement (PPA) by the government.
O6: The possibility to develop, technology transfer, and industry development.
O7: Decreasing environmental pollution in Iran.
O8: Academic interests, and also researches and academic projects in the field of renewable energy.
T-Threats: T1: Low prices for fossil fuels.
T2: Low purchase price of electricity.
T3: Low tendency of private and foreign investors.
T4: Lack of comprehensive knowledge of managers about the benefits of renewable energy.
T5: Lack of creation and networking of scientific and academic groups with the presence of industrial managers and experts.
T6: Lack of infrastructure for the development of renewable energy technology.

A. The SWOT matrix of the SO and ST strategies:

The strategies of the strengths to meet the opportunities (SO) were applied to provide the most utilization of external opportunities by using internal strengths: SO1. Using renewable energy potentials in order to mitigate the effects of climate change.
SO2. Policy making to encourage the private sector to invest on the renewable energy projects.
SO3. Attempting to persuade the policy makers of national energy sector for supporting to develop renewable energies in order to produce more electricity non-fossil fuel consumption.
SO4. Supporting national industries of renewable energy plants and the attempts to achieve high technologies by supporting research affairs and academic activities.
SO5. Using Iranian mines with high purity of silica in Iran in order to produce solar cells.
SO6. Extensive using renewable energies for faraway towns and villages.
SO7. Advertising and public culturization the benefits of renewable energy including reducing GHGs and environmental pollution.
SO8. Creating the renewable energy market.
SO9. Planning and supporting needed research projects of national research centers and Iranian universities.
SO10. Increasing and modifying guaranteed electricity purchase tariffs (GEPTs) of renewable energies.
SO11. Providing loans and government assistance to support research and academic projects in order to produce and market.
SO12. Supporting joint researches and international cooperation by foreign research centers and universities.
SO13. Planning for the widespread use of renewable energies in off-grid areas.
SO14. Clarifying and reporting the benefits of renewable energy developments to the authorities and developing the training programs. SO15. Presentation the results of new researches and advanced pilot projects.
SO16. Establishment of the strategic committee included main members of effective persons and decision- makers of the Ministry of Science the Ministry of Energy, and the Ministry of Industry to monitor the performance of technology development and research plans.

B. The strategies of protecting strengths against threats (ST):

In implementing the ST strategies, attempts are made to take some mechanisms through internal strengths to prevent or eliminate the negative impact of external threats as follows:
ST1. Establishment of the renewable energy fund and supply financial resources through shaping a competitive market for investors and suppliers and also increase financial security and electricity exporting.
ST2. Explain benefits of renewable energies to energy suppliers.
ST3. Providing fund, modifying GEPTs, and commercializing technologies.
ST4. Encouraging Iranian universities for training, developing, and promoting human resources in the field of renewable energies.
ST5. Using the academic and research activities to solve the technological problems.
ST6. Designing plans to promote using of renewable energy by people.
ST7. Attempting to convince traditional electricity producers for investing in renewable energies.
ST8. Setting laws and regulations in order to develop renewable energies in heavy industries with high energy consumption.
ST9. Advertising and public culturization renewable energies through announcing the results and benefits of the research projects and other news by the media.
ST10. Encouraging new investors for investing in renewable energies by knowledge-based companies.
ST11. Strengthening financial processes such as long-term incentive loans regarding the positive results from research projects by knowledge-based companies.
ST12. Using the global carbon market opportunity.

C. The strategies of reducing weaknesses related to the opportunities (WO)

The purpose of WO strategies is to take advantage of the opportunities in compensating the weaknesses. These strategies are as follows:
WO1. Setting and localization the national standards of the renewable energy technologies.
WO2. The laws to encourage the private sector to invest to develop renewable energy technologies.
WO3. Providing renewable electricity export opportunities in order to develop renewable energies.
WO4. Supporting the technology localization by the internal knowledge-based companies and research centers.
WO5. Inverse engineering of the technologies which needed in national manufacturing.
WO6. Collaboration with international organizations and technical advisors in order to technology transfer.
WO7. Establishing and developing the infrastructures such as research, training, testing, certificating and standardizing centers of the renewable energy systems.

D. The strategies of addressing the weaknesses related to the threats (WT)

The purpose of WT strategies is to reduce internal weaknesses and avoid external threats. These strategies are as follows:
WT1. Improving international political relations with advanced countries in order to technology transfer of renewable energy systems.
WT2. Providing the export opportunities to produce renewable energy systems.
WT3. Modifying and increasing GEPTs of renewable energies by the government.
WT4. Modifying guaranteed electricity purchase contracts of renewable energies to encourage investors and using other methods for purchasing renewable electricity.
WT5. Using carbon market to compensate costs of renewable energies.
WT6. Public culturization for the use of renewable electricity and their public demand from the government to supply the energy they need renewable energy.
WT7. Formulating incentive rules for the volunteers using the renewable electricity.
WT8. Strengthening human resources specialized in renewable energies through promoting training programs at university centers to assure investors of sufficient internal specialist expertise.
WT9. Establishing the centers of research, training, testing, certificating and standardizing on renewable energy systems. In Fig.3, it was shown a comparison and ranking of the 3 important priorities of the SO, ST, WO, and WT strategies which based on the results of the AHP model. The most important priorities that are to enhance the strengths regarding the opportunities (SO) were obtained. The three priorities are: 1- SO10. Increasing and modifying guaranteed electricity purchase tariffs (GEPTs) of renewable energies. 2- SO8. Creating the renewable energy market. 3- SO11. Providing loans and government assistance to support research and academic projects in order to produce and market.

The three strategies of protecting the strengths against threats (ST) were identified as: 1- ST1. Establishment of the renewable energy fund and supply financial resources through shaping a competitive market for investors and suppliers and also increase financial security and electricity exporting. 2- ST11. Strengthening financial processes such as long-term incentive loans regarding the positive results from research projects by knowledge-based companies. 3- ST8. Setting laws and regulations in order to develop renewable energies in heavy industries with high energy consumption. The three WO priorities included: 1- WO7. Establishing and developing the infrastructures such as research, training, testing, certificating and standardizing centers of the renewable energy systems. 2- WO4. Supporting the technology localization by the internal knowledge-based companies and research centers. 3- WO2. The laws to encourage the private sector to invest to develop renewable energy technologies. The three strategies were addressed in the weaknesses with respect to the threats (WT) included: 1- WT4. Modifying guaranteed electricity purchase contracts of renewable energies to encourage investors and using other methods for purchasing renewable electricity. 2- WT3. Modifying and increasing GEPTs of renewable energies by the government. 3- WT1. Improving international political relations with advanced countries in order to technology transfer of renewable energy systems.

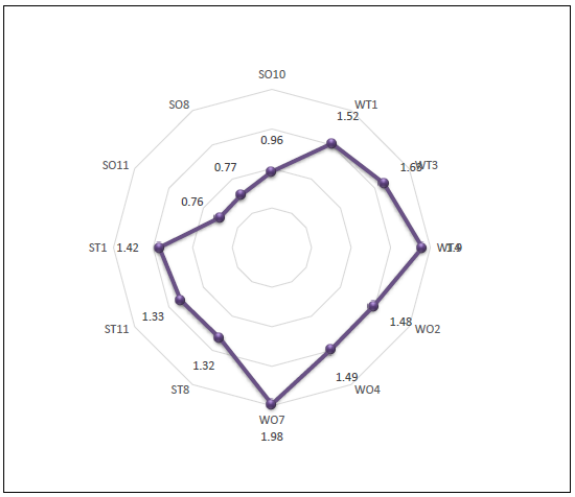

Fig. 3. Comparison of the most important priorities of the SO, ST, WO, and WT strategies

4. CONCLUSIONS

A hybrid of SWOT and AHP methods were applied to investigate the challenges facing Iranian renewable energies development and recognize management solutions. Based on the results, the most important strategies included modifying guaranteed electricity purchase tariffs (GEPTs) of renewable energies, establishment of the renewable energy fund and supply financial resources through shaping a competitive market for investors and suppliers and also increase financial security and electricity exporting, establishing and developing the infrastructures such as research, training, testing, certificating and standardizing centers of the renewable energy systems, and improving guaranteed electricity purchase contracts of renewable energies to encourage investors and using other methods for purchasing renewable electricity. International cooperation is an important factor to develop the renewable energy in Iran. Unfortunately, sanctions created obstacles to increase the foreign investment and technology transfer. The foreign policy can help to extend

the international projects and plays the main role for attracting foreign investors. Although, the renewable energy development is feasible in Iran. But the international supports in order to determine the economic priorities, attraction of external financial resources, and the investment of the private sector, international collaborations, and research cooperation are necessary. It is critical to inform the authorities and the public. And also it is going to new concepts of Iran renewable energy economics. It is suggested for the future research and studies, other plans and strategies, such as the bartering of oil or petroleum products with renewable power plants or settlements of exchange of fuel-saving mechanisms and the renewable energy equipment.

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