Investment Prioritization in Renewable Energy Resources with Consideration to the Investment Criteria in Iran

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ABSTRACT

A competitive environment and private sector participation are essential for the economic utilization of renewable energy. Although the private sector is the driver of most industries, private investors are usually cautious about new technologies, particularly in renewable energy. With focus on the desires and concerns of the private sector, this article addresses the main questions private investors have about the identification and evaluation of renewable energy investment opportunities in Iran. The analysis shows solar energy is the best source for private sector investment. Further, for each investment criteria the more attractive energy sources are also presented as byproducts of the research.

Keywords: Renewable Energy, Investment, Private Sector, Decision-Making, Analytic Hierarchy Process (AHP), Iran

INTRODUCTION

Although Iran is known as a wealthy country in terms of all kinds of energy sources, most of its production and demand is oil and gas. According to EIA reports, the dominant role of carbon-based resources in supplying primary energy was 97% in Iran in 2007 in which the share of electricity generation was more than 93% (of which 75% is from gas and 18% from oil) [1]. Annual statistical reports show that Iran has an inefficient structure in energy systems [2]. For instance, while the country is the third largest producer of natural gas in the world after United States and Russia, it imported gas for domestic consumptions in 2009 (Figure 1) [3]. This demonstrates Iran has faced with many challenges in optimal

utilization of hydrocarbon resources [4]. Due to the rich and diversified potential of renewable energies (RE) in Iran, development of RE utilization as cleaner energy resources is one of the alternatives to minimize the carbon-based fuels usage and decline the environmental footprints [5][32]. For example, two months solar radiation in Iran is equal to total ever-discovered reservoirs of fossil fuels in the country [6]. Further, renewable energies (RE) provide a nearly unlimited supply of relatively clean and mostly local energy and considerable opportunities [7].

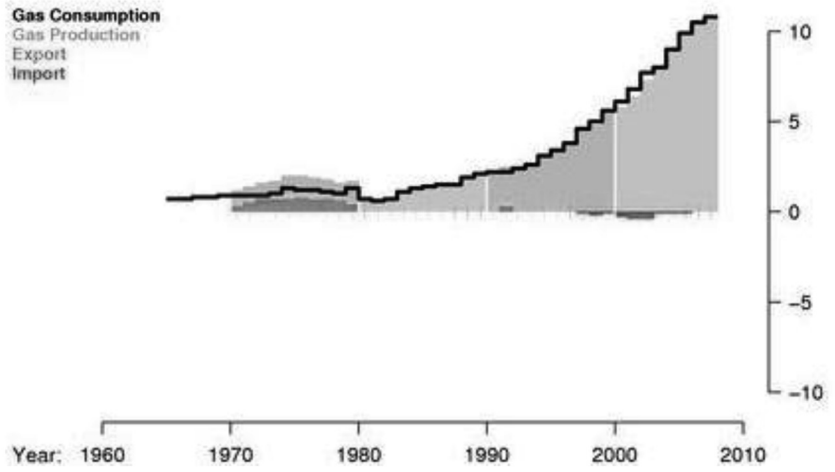

Figure 1. Gas consumption, production, export and import trends in Iran (billion cubic feet per day) [3].

Most of the energy market in Iran is under government control. This does not mean that this market is monopolistic. Following the government policy towards privatization of state enterprises and replacing RE resources for fossil fuels, the Iranian government is supporting the private sector, with emphasis on the exploration, production, exploitation, and transmission of new energy resources [8]. However, only 38% the goals of Iran's fourth national development plan in RE have been achieved [9]. The development barriers can be studied from different perspectives such as lack of a dynamic strategic management and non-optimal utilization of human resources [4].

Since governmental policy is one of the important factors on market and industrial development, to have the application of RE economi-

cally, governments should try to diffuse RE resources pervasively by supporting the private sector [10][33]. For instance, not only the share of private sector in electricity generation is about 80% in US, but also 75% of electricity sales to final customers are undertaken by private utilities [11]. Therefore, participation of the private sector is an important driver of competitiveness in energy industry, particularly in the RE industry.

Despite a beneficial future including relatively short-term profitability of RE, domestic and international investors have still doubts and concerns about entering and investing in the Iranian market [10]. Since investors are committing their capital for the economic life time of the assets, they need to cover all significant aspects and risks before making an investment decision. It means there are important considerations that an investor wants to know to make a good and informed decision.

This research discusses the prioritization and selection of the best RE source for investment from the investor viewpoint. The analysis is based on multi attribute decision-making theory (MADM) and by using the analytic hierarchy process approach (AHP). Due to the high reliability and validity of such methodology, the results and approach can be applicable in decision making of investors, policy makers, and researchers of the different countries with the same conditions in the Middle East, Asia, and Africa.

LITERATURE REVIEW

The Renewable Energy Potential of Iran

In this section, RE sources in Iran with commercial potential are reviewed from engineering and business viewpoints.

a) Solar Energy

Iran is situated at 25˚ to 40˚ north latitude in a region with 1,531,595 km^2 of dry land. The country has one of the highest solar energy receptions in the world and is the 18th largest country. The total solar radiation absorption is estimated between 1800 and 2200 $kW.h.m^{-2}$ per year; higher than the global average [12]. Because of its location, Iran has over 280 sunny days per year (Figure 2) [13].

Studies show that solar energy has a strong potential for business investment. It can be utilized by different systems and cleaner productions [14]:

- Solar thermal energy for domestic, industrial, and power plants usages
- Direct conversion to electricity by photovoltaic systems

The solar thermal power plants can be classified in three main groups:

1 Power plants with collectors of linear parabolic mirrors
2 Power plants with central receivers installed on a tower in which sunlight is reflected by large mirrors called heliostat
3 Power plants with reflectors of parabolic dishes

In addition to power plant-based functions of solar energy, off plant thermal functions are considered as hot water supply by solar water heaters for washing and bathing, heating-cooling and solar air conditioning, solar desalination, solar drier, solar ovens, and solar furnaces.

b) Hydro power

Rain and snowfall in mountains as well as water flow in steep slopes of rivers are prime energy resources for hydro power plants in Iran. Absence of fuel consumption and consequently fossil fuel savings are the benefits from hydropower plants. In addition, the average operational lifetime of these plants is relatively higher than thermal plants so that there are currently some active hydro power plants built 50 to 100 years ago.

Overall, the potential of electricity generation by Hydropower in Iran is 50TWH [15]. There are numerous drainage basins in Iran among the most important ones: Karoon, Karkheh and Dez. Water resources control by construction of embankment dams is one of salient achievements in water management. The production capability of hydroelectricity is more than 30 GW in Iran [16]. By the end of 2007, the total installed capacity of hydroelectric power plants was 7422.5 MW [13].

c) Wind Energy

Nowadays, thousands of wind turbines are functioning in the world maintaining the production capacity of 73,904 MW, of which 65% is produced in the EU [17]. Among other RE alternatives, wind electricity has the highest growth rate in 21st century so that the wind power production in the world has quadrupled between 2000 and 2006. Iran is located in the

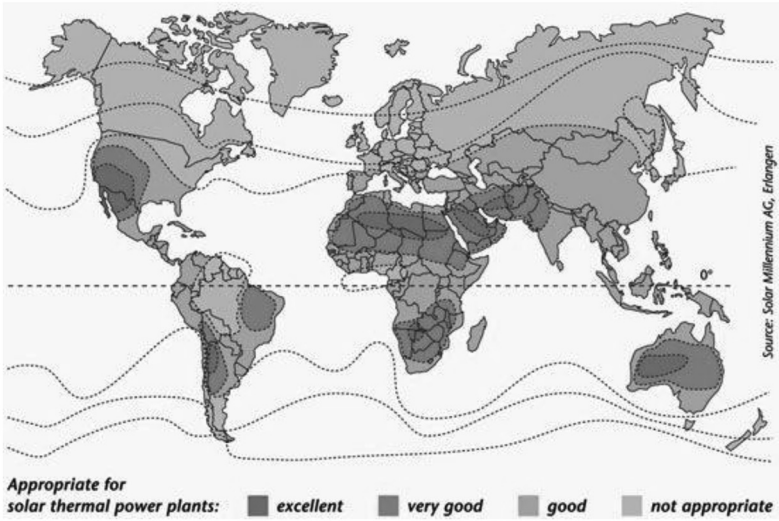

Figure 2. World situation insight of sun rising [17]

path of main air currents between Asia, Europe, Africa, Indian Ocean and Atlantic Ocean of which the most important ones are [16]:

- Central pressure current of Central Asia in winter
- Central pressure current of Indian Ocean in summer
- Western current from Atlantic Ocean and the Mediterranean Sea particularly in winter
- Northwestern current in summer

d) Geothermal Energy

Geothermal energy may be exploited in two ways in Iran: power plant generation, and off-plant utilization. In general, geothermal power plants are classified in two important groups; geothermal power plant with two-phased fluid, and geothermal power plants with single-phased fluid. Moreover, direct utilization or off-plant functions of geothermal energy in Iran can be applied in warm water swimming pools, greenhouse applications, domestic heating, fish reproduction basins, snow melting and road defrosting, and heat pump.

Since Iran is located on the global geothermal belt, the Power Ministry and Nuclear Energy Organization of Iran have implemented rigorous study and research in this field as other renewable energy applications. Geothermal energy power plant in Meshkinshahr is one of these

efforts performed by the Power Ministry. According to estimations, the resource reaches the temperature of 260˚C and power plant capacity of 250 MW [18].

e) Biomass

Biomass resources consist of forests and forestry residues, agricultural products and residues, industrial waste and sewage, solid waste, municipal waste, and livestock waste. The first digester for methane generation in Iran was built in a village called Niazabad in 1976 [16].

The vastness of the country as well as quantitative and qualitative versatility of biomass resources offers a proper competence for electricity generation from biomass in Iran.

Public Policies toward Diffusion of Renewable Energy among Private Sector

Regarding to situation of energy consumption in Iran, the Iranian Ministry of Energy as a responsible organization for development and generation of electrical energy commenced surveys and investments in the field of RE (No. 161299 on April 18, 2000, Ministry of Energy's). The investments led to the establishment of an independent research organization but belong to the Ministry named Renewable Energy Organization of Iran (SUNA) with the help of World Bank [19]. On the other hand, the Ministry of Energy as the main RE policy maker has tried to encourage the participation of private sector by enacting the different laws (Table 1) [10].

OVERVIEW THE BARRIERS OF DIFFUSION OF PRIVATE SECTOR INVESTMENTS IN RENEWABLE ENERGY

Several investigations have been done to study different aspects of diffusion of private sector investment in the energy industry. Zuluaga et al. have reviewed financial factors influencing on investment in energy industry such as interest rates and taxes in new technologies etc. [20]. According to Sardianou, the obstacle factors on energy investments are mainly financial limitations, economical and market parameters, and organizational and human related factors [21]. Battaglini et al. discuss the most important aspects of the perceived risks from energy investors perspectives such as poorly defined financial uncertainties, technologies

uncertainties, policy uncertainties, local political obstacles to transmission access rights, import dependency etc. [22]. In addition, limit researches have focused on the desires and constrains of private sector in RE industry particularly in developing countries [10] [9][2][23].

The process of renewable energy supply chain includes five main domains showed in the Figure 3. Each domain has an attractive potential for private sector investment [24]. Despite the importance of RE in electricity generation, attractive potentials of RE investment in Iran, and government encouragement packages, the lack of investors illustrates gaps between investor's expectations and government policies. As starting a private investment involves delicate decision making, there are important indexes that investors probably like to assess before investment (section 2.4).

Figure 3. Domains of RE supply chain

REVIEW THE PRIME CRITERIA FOR PRIVATE SECTOR PARTICIPATION IN RENEWABLE ENERGY INVESTMENT

To understand the different dimensions of decision making among private investors, the researchers of this study have investigated on the investor's criteria to RE investment in Iran. Therefore, seven criteria have been prescribed to evaluate the participation of the private sector in RE investments [10]. The criteria have been identified based on an extensive qualitative research, and classified from three dimensions of politics and business, engineering, and environment (Figure 4). Following, each factor is reviewed briefly

a) Engineering Efficiency Index

Energy efficiency is categorized in two different levels: efficiency in products and services, and efficiency in energy basis. According to the research, efficiency is one of the two core bases of sustainable energy policies in addition to renewable energy [10]. Since it can be a factor for creation of competitive advantage as well as increasing the customer satisfaction, understanding the energy efficiency is important for an investor [10]. More efficiency leads to the further attraction in consumption and consequently more attraction in investment.

Table 1. Government encouragement packages of RE development [10]

Piecemeal elimination of government subsidies for electricity and energy fossil fuels to offer real prices from the beginning of 2011
Performing holistic geological and geographical research of potential areas of exploitation and providing an atlas for locations
Loans and financial incentives for investment in RE providing by Energy Ministry and The Environment Protection Organization
Guaranteed purchase of electricity exploited form RE by Energy Ministry from the private sector in long-term contracts, according to Governmental Financial Regulations Act.62
Providing the possibility of renewable energy business and energy market in Iran
Permitting the private sector to export their sustainable electrical energy to the neighbor countries
Incentives arising from pollutant emissions control and greenhouse gases control policies,
Waiving the rent of lands used by the private sector to build power plants to produce renewable energy
Required technological supports and tax waivers for importing the relevant equipment and technology

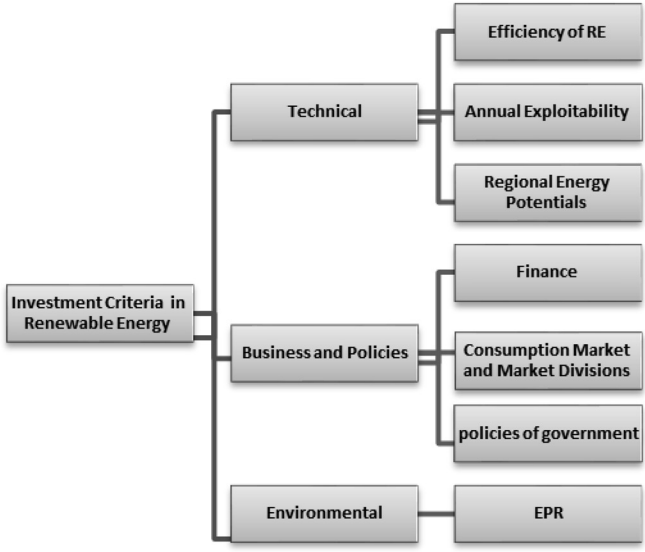

Figure 4. Identified criteria for investment in RE from private sector point of view [10]

b) Annual Exploitability Index

One of the concerns of investors in commerce of a business is the period that a product or service can be efficiently exploited [10]. Hence, the investor's awareness about the accessibility and annual exploitability of renewable energy is an important factor to evaluate the sub-indices such as investments return index, operation risk, etc.

c) Regional Energy Potentials (Geographical Distribution)

Energy resources are always considered as a constraint that may even endanger a business from a competitiveness viewpoint. Therefore, the number of regions that RE sources can be readily utilized present more attraction for investment. This assumption would be considered from different aspects. And the most important one is distribution and harvesting potentials.

d) Finance Index (cost-effective deployment)

Since one of the main interests of investors is to minimize the costs of renewable energy generation, introducing an index for indicating the actual costs for each type of RE is important for private sector. According to Sardianou, a large number of calculations are necessary for estimating an investment's profitability that investors would like to now before they decide to invest in energy industry [21]. Because RE technologies will improve with time, financial investment of renewable energy (project costs) generally gets cheaper.

e) Consumption Market and Market Divisions

As end-user markets provide more advantage compare to mediator markets for suppliers, they are one of the important interests of private sector [25]. The crucial issue in consumer market is advantage-cost of a product or service. To encourage an end user to purchase a new product, they should be satisfied with what they pay for the new product compared to what they already get (i.e. the challenger's value proposition).

f) Conformity with Supportive Policies of Government

This factor is to identify the supportive governmental policies for investing on RE. In other words, accredited degree of government to renewable energy projects is important from investor viewpoint. The Iranian governmental policy seems to incentivize the private sector to invest in this area especially in some RE sources.

g) EPR

One of the main factors of RE investors for investment in energy sector is the environmental performance of RE that called Energy Payback Ratio (EPR) [26]. The factor is important from customer demands (market and consumer psychology), sustainability, and possible future rules. According to the reports, the electricity industry contributes more than 37% of the world's carbon emissions that is predominant from burning fossil fuels [26]. EPR is calculated by the inverse of energy intensity (EI). The Energy intensity is the ratio of the total energy used for construction, operation and decommissioning (E), to the electricity output of the plant/device over its lifetime (ET).

RESEARCH METHODOLOGY

Research Type and Strategy

The research is an applied and a descriptive research (Figure 5) and tries to response to this question: "Considering the important criteria of RE investment, which RE sources have a higher priority for private sector investment in Iran?" The work is an objective research insight of epistemology and since the researchers just control the right process of doing research, the research strategy is a survey research (ontology viewpoint) (Figure 6) [27] [28]. Therefore, identification of the best RE sources from five common alternatives is the cardinal purpose of the research. To analyze, evaluate, compare, and rank alternatives, the analytic hierarchy process (AHP) is used as one of the best and valid methods of multi attribute decision-making (MADM) [29]. AHP is an effective quantitative method especially insight of sensitivity analysis compared to other MADM methods.

Empirical Survey

The AHP is based on three principles: hierarchical structuring, weighting, and logical consistency. Pairwise comparison, homogeneity, independence relation, and expectation are the assumptions of this technique [29]. Figure 7 shows the decision problem that is represented in a hierarchical structure. Two different questionnaires consist of pairwise comparisons among the seven criteria and pairwise comparisons between five alternatives (RE sources) with respect to the criteria were designed. The phrasings of the questions were carefully formulated to

reflect the scales intensity of relative importance suggested by Saaty (Figure 8) [30]. Therefore, the validity of the questionnaires is confirmed by using standard tables [31].

Data Collection

The first questionnaire is related to pairwise comparisons of seven criteria. The second one is also related to the pairwise comparisons of alternatives (RE sources) among the criteria. The first group of responders are domestic investors, especially those working in or intending to invest in the energy industry in Iran. They responded to the first questionnaire. The selected investors are working in three different kinds of companies: contractors of engineering projects, financial organizations, and manufacturing firms. The companies were found in official government websites such as http://besi.ir, http://industry-info.ir/or http://www.tsitco.com/en/. Thirty-one samples from 14 companies were selected randomly, and the questionnaires were distributed video conference, phone interview, and email. The selected companies are working with minimum capital of €100,000. The ages of responders are between 29 and 64 with bachelor degree minimum. The respondents compared the priority of each couple of criteria in the first questionnaire.

The second group of responders is energy and power experts, researchers and professionals in the energy sector. They are working in ministry of energy and related departments in the Iranian universities. The reason for this careful selection is related to the high level of needed knowledge in the fields of energy and renewable sources that a responder needs to compare pairwise resources in each criterion. This

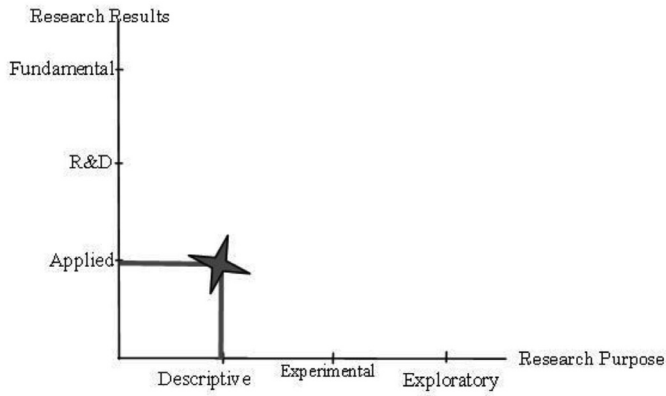

Figure 5. The framework of the research [27]

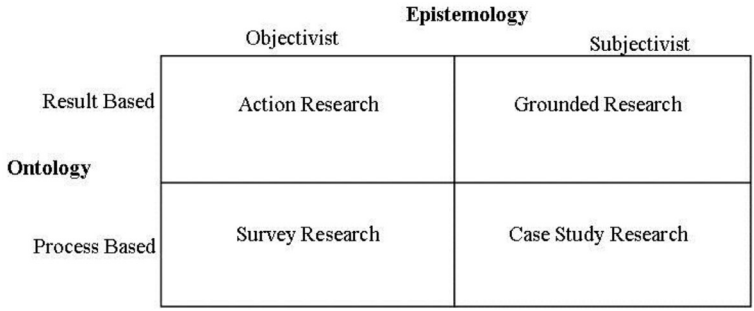

Figure 6. The research strategy [28]

level of professional awareness is the point that an investor usually has not about RE sources in each criterion. Therefore, this selection improves the reliability of the research. The numbers of selected experts for the second questionnaire were 35 with the minimum master degree in energy, environment or related majors. In the second questionnaire, the researchers asked respondents to compare the priority of each couple of RE sources in each seven criteria. The numbers of respondents for both questionnaires are quite enough for AHP analysis.

Data Analysis

Expert Choice 11 software was used to analyze data. A decision model typically consists of five steps: (1) structuring the decision model, (2) entering alternatives, (3) establishing priorities among elements of the hierarchy, (4) synthesizing, and (5) conducting sensitivity analysis. The inconsistency rates of responses for each pairwise comparison matrix have been checked by the software. The researchers found that three of the responses (questionnaire #1) caused the rates further than 0.1. Therefore, they were removed from analyzing process. It helps to ensure about the reliability of the research [31]. The first result is the weights of criteria shown in Figure 9. It is evident that the market division has a contribution of 27.7% to the goal as a most important factor whereas the EPR contributes the less important with 4.2% to the goal.

After calculating all priorities and inconsistency indices, the relative weight of each RE source for each criteria were determined (Figures 10 to 16). These minor results can help to investors to make a good decision if they want to identify the best RE resource in one index. For instance, from market division index, the solar energy is the best resource for private sector investment (36.3%) (Figure 14).

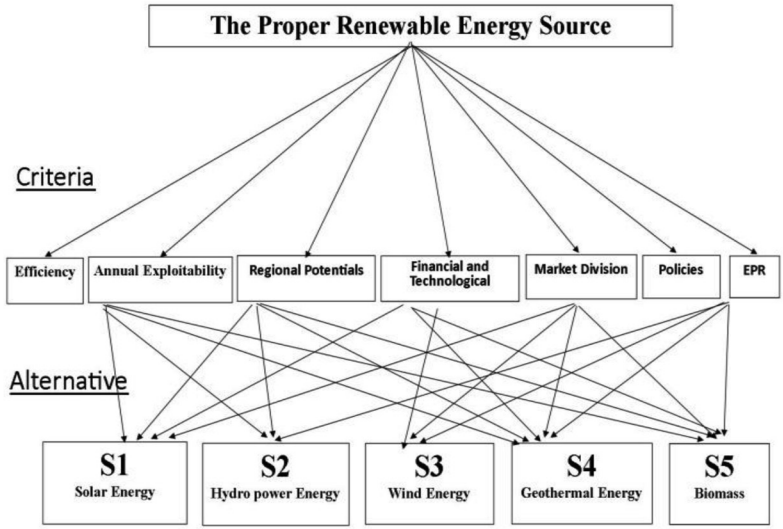

Figure 7. The hierarchical structure of the research

Intensity of importance	*Definition*	*Explanation*
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one over another
5	Strong importance	Experience and judgment strongly favor one over another
7	Very strong importance	As activity is strongly favored, and its dominance is demonstrated in practice
9	Absolute importance	The importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above

Figure 8. AHP scales intensity [30]

The final result of RE sources is shown in Figure 17. As the figure indicates, the "solar energy" is the best source for private sector investment in Iran. It contributes with 28, 9% (0.289) to the goal. After solar energy, the "wind energy" is in the second rank (0.207). Table 2 summarizes the priorities of each source.

DISCUSSION AND CONCLUSIONS

The regional potential (primarily a region's latitude) in conjunction with constraints, hazards, and the environmental impact of carbon-based fuels and nuclear energy are some of the most significant reasons for the development of renewable energy in the world. Despite abundant supply of the primary sources, the development of RE in the Middle East and Iran is slow due to abundance of fossil resources in those regions. For the successful investment and utilization of RE, the underlying projects and commercialization need to be competitive. Therefore, participation of private sector is the main driver of RE development in developing countries. This can't happen, however, without effective government intervention.

In this article, the important RE resources in Iran were reviewed, prioritized, and ranked considering a private investment. Thereby, solar energy was identified as the best RE source for private investment in Iran and even in the Middle East. After that, wind and hydropower sources are in the second and third priorities for investment, respectively. Further, the minor results of this survey show the situations of each RE sources in each criterion (Table 2). These results should be valuable to analysts and policy makers. For instance, investors can identify which RE source is better for investment from their considered indicator. On the other hand, public policy makers can review and create their supportive policies based on the investors' interests and priorities. Finally, the survey provides a guideline for researchers interested in the Iranian RE situation and market.

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Figure 9. The weights of criteria (Analyzed from questionnaire 1)

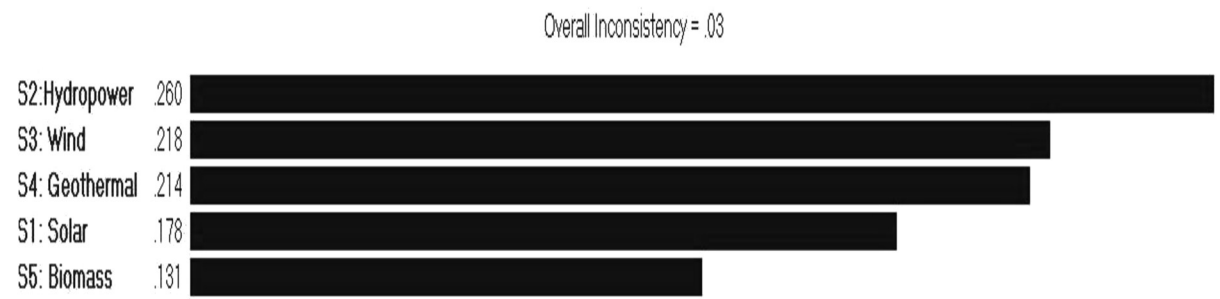

Figure 10. Prioritization of the RE sources according to the Efficiency index

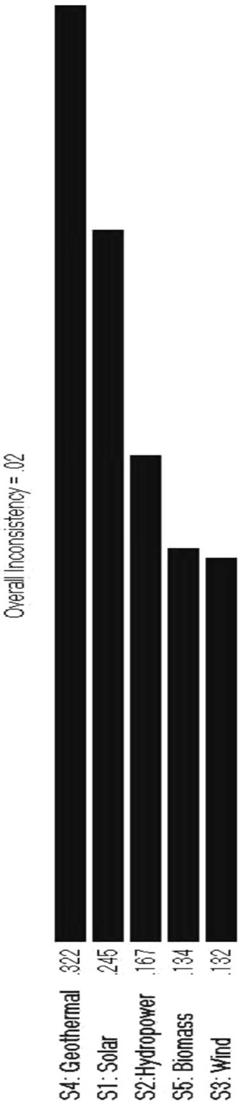

Figure 11. Prioritization of the RE sources according to the Annual Exploitability index

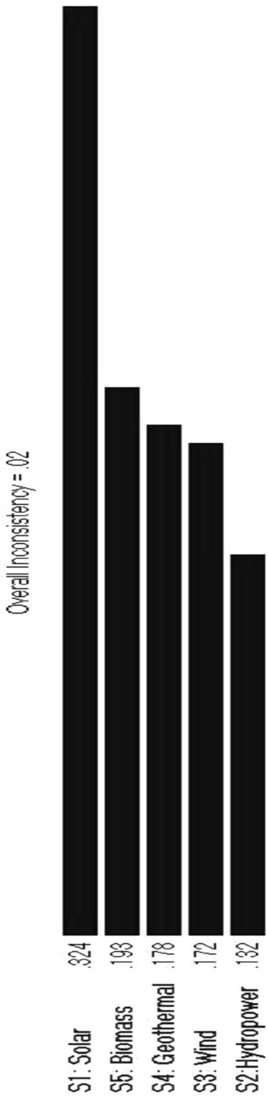

Figure 12. Prioritization of the RE sources according to the Regional Energy Potentials index

Figure 13. Prioritization of the RE sources according to the Finance index

Figure 14. Prioritization of the RE sources according= to the Consumption Market and Market Divisions index

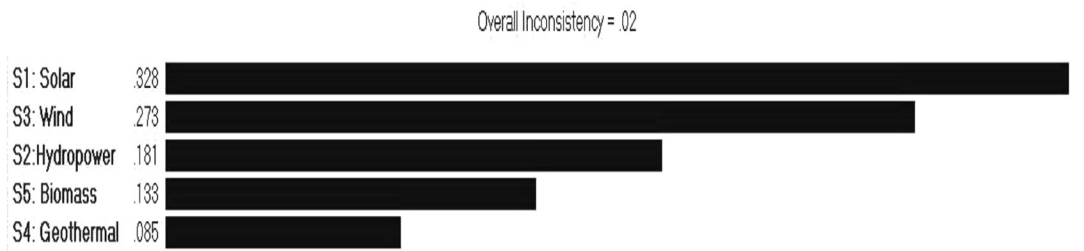

Figure 15. Prioritization of the RE sources according to the policies of the governmental policies index

Figure 16. Prioritization of the RE sources according to the EPR index

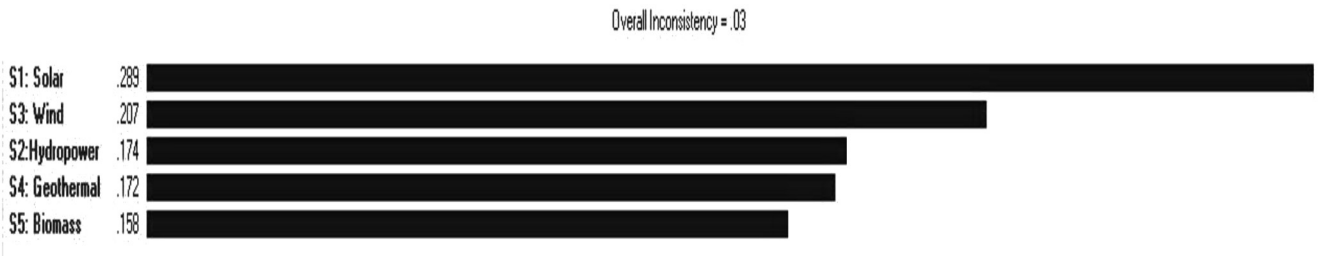

Figure 17. Final priority results (Overall)

Table 2. Ranks of each RE source in each criteria and overall

	Overall	Efficiency	Exploitability	Regional	Finance	Market	Supports	EPR
Solar	1	4	2	1	1	1	1	4
Hydro power	3	1	3	5	4	5	3	1
Wind power	2	2	5	4	3	2	2	2
Geothermal	4	3	1	3	5	3	5	3
Biomass	5	5	4	2	2	4	4	5

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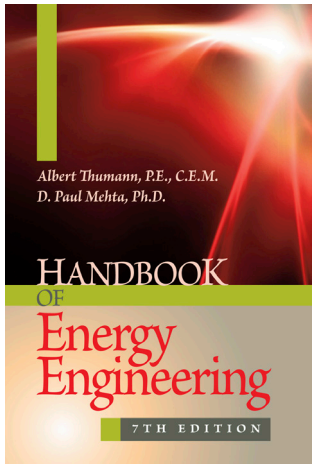

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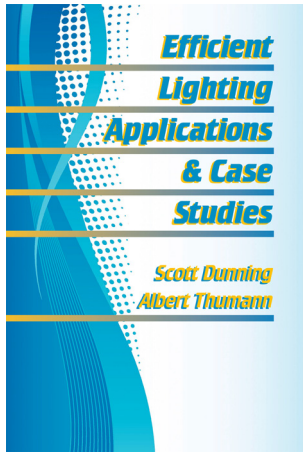

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