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The Role of Renewable Energies in Sustainable Development: Case Study Iran

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Abstract: A series of various factors such as limitation of fossil fuel resources, negative impacts on environment, fossil fuels prices, political disputes and their effects on supplying sustainable energy are among the reasons which have made many politicians, energy and environment experts move toward the development of a modern structure to secure supply of energy, environment protection and efficiency improvement of energy systems. Hence, most countries have begun to realize that the need for sustainability in energy production and consumption is significantly vital. Therefore, tracking the progress of sustainability is essential. The aim of this paper is to present a set of indicators for Iran, based on the Helio International Sustainable Energy Watch (SEW) indicators, that shows how to track progress toward sustainability in the energy sector. Due to SEW framework, Iran is the closest to sustainability target based on indicators for access to electricity. Iran performs worst on the indicators for CO_2 emissions and energy intensity. Iranian's private sectors had already signed contracts to build plants (more than 600 MW) based on biomass systems and newly developed wind energy (500 MW). Based on Iran Renewable Energy Organization (SUNA) remarks the private sector has submitted a proposal for generating 3000 MW. The objective of present work is to highlight fundamental challenges about the development of renewable energy and policy framework requirements for achievements of sustainable energy in Iran.

Key words: Sustainable development · Renewable energy · Sustainability indicators · Energy policy · Sustainable Energy

INTRODUCTION

A public concern over the environmental consequences of greenhouse gas emissions from fossil fuels, increasing trends in use of renewable energy sources became an important energy policy target in most parts of the world. Use of renewable energy sources can reduce the speed of global warming and serious impacts of climate change from burning fossil fuels. Renewable energy is derived from sources that are being replaced by nature, such as water, wind, solar or biomass [1]. The use of renewable energy (RE) offers a range of exceptional benefits, including: decrease in external energy dependence; boost to local and regional component manufacturing industries; promotion of regional engineering and consultancy services specializing in the utilization of RE; increase in R&D, decrease in impact of electricity production and transformation; increase in level of services for the rural population; job creation, etc. [2]. Renewable energy sources are the fastest growing energy source in the world and various projections indicate that these resources will have huge contribution in the future [3-5].

The concept of sustainable development has enjoyed widespread coverage in the literature and in discussions at diverse levels [6,7]. The concept of sustainable development (SD) was adopted by the World Commission on Environment and Development. There is agreement that SD involves a comprehensive and integrated approach to economic, social and environmental processes [8,9]. A sustainable development approach aims to deliver services that meet basic human needs, but in a cleaner and more efficient manner that can be sustained for long term [10].

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Table 1: Energy indicators for SD in the world

Investigation area	Cited references
Energy for sustainable development in China	[18]
Energy and Sustainable Development in Bangladesh	[19]
Energy and Sustainable Development in South Africa	[20]
Energy and Sustainable Development in Taiwan	[21]
Renewable energy and sustainable development in Turkey	[22]
Energy and Sustainable Development in German	[23]
Indicators of sustainability for the energy sector: a South African case study	[24]
Energy and Sustainable Development in China	[25]
Energy and Sustainable Development in India	[26]
Energy and Sustainable Development in New Zealand	[27]
Energy and Sustainable Development in U.S.A	[28]
Energy and Sustainable Development in Iran	[29]
Sustainability of energy production and use in Iran	[30]
Energy indicators for sustainable development in Baltic States	[31]
Review and use of the Algerian renewable energy for sustainable development	[32]
Energy sustainability from analysis of sustainable development indicators: A case study in Taiwan	[33]
Development of three cornerstones for a sustainable energy future in Iran	[34]
The role of energy sector in sustainable development in Iran	[35]
On energy for sustainable development in Nigeria	[36]
Energy production trend in Iran and its effect on sustainable development	[37]
Energy for sustainable development: A case of developing countries	[38]
Renewable energy, sustainable development and environmental protection in Ksours (case of Algeria)	[39]

In this modern era, energy is central to sustainable development and prosperity of a society. In attaining sustainable development, increasing the energy efficiencies of processes utilizing sustainable energy resources plays an important role [2, 11, 12]. Various alternative energy sources in harmony with nature and addressing the pressing needs of social, environmental, economical aspects. Finally, the energy and security problems are being proposed [13]. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions for achieving sustainable development. Hence, in recent years, special attention is paid to renewable energy resources which are alternative replacement of fossil fuels [14].

Iran with its young population and growing energy demands, its fast growing urbanization and its economic development, has been one of the countries in the world with high rate of energy consumption [15]. It holds the world's second largest natural gas reserves and also the OPEC's second largest supply of oil [16]. Iran is one of the richest countries of the world in terms of various energy resources, since it enjoys extensive resources of fossil fuels such as petroleum and natural gas in one hand and possessing high potentials of renewable energies, such as hydroelectric, solar, wind, geothermal and tidal, on the other hand. Countries like Iran with abundant oil and gas reserves should not only rely on these resources and with no further delay should adopt a comprehensive mix energy policy and must plan for the development of all kind of alternative sources of energy [17]. With regard to proposed changes to actualize the prices of energy carriers due to required fuel and power supplies in Iran, the exploitation of renewable energy resources and development of these energies application have become more consequential [16].

HELIO international organization is composed of a network of energy analysts who identify, assess measure and publicize the contribution of energy systems and policies to economic development (sustainable and equitable development). Sustainable Energy Watch (SEW) reports are prepared by the HELIO for most countries. It measures progress towards sustainable energy and development practices. Table 1 represents an overview of scholarly work that has influenced the energy indicators for sustainable development presented in this paper.

The method of using indicators for sustainable development provides a prefect sound for policy-makers to identify synergies and trade-offs between options to evaluate their economic, social and environmental dimensions [10]. In this regard, this paper attempts to present a set of energy indicators for Sustainable Development in Iran.

This paper is organized as follows: Sustainable development and state of Iran section presents 8 indicators for the following energy and SD in Iran.

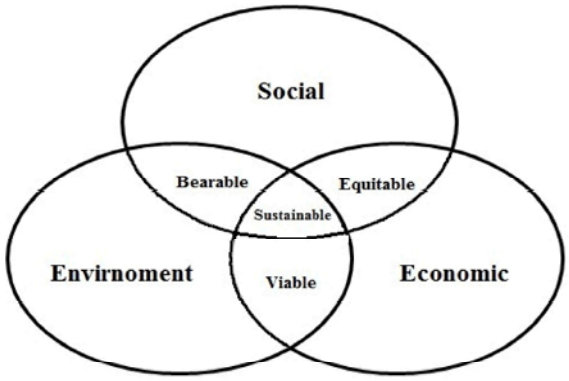

Fig. 1: Scheme of sustainable development and convergence of three constituent parts

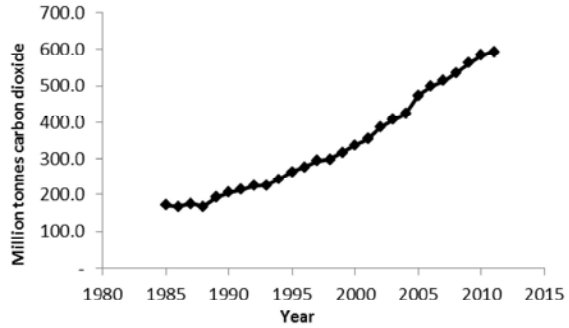

Fig. 2: Iran's CO_2 emissions [44]

Fundamental challenges about development of Iran's renewable energy are presented in the next section. Policy framework requirements for renewable energy development are presented. A brief overview about renewable energy development challenge and requirements is discussed. Finally, as a summary of remarks concluding statements are presented in conclusion.

Sustainable Development and State of Iran: Sustainable development is defined in various schemes, but including this landmark which first appeared in 1987 from Our Common Future, also known as Brundtland Report:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [40]. Sustainable development is based on three pillars: environment, economy and social aspect. Fig 1 shows that the scheme of sustainable development and the convergence of three constituent parts.

Energy is central to improve social and economic well-being and is indispensable to most industrial and commercial wealth generations and it is the key factor for relieving poverty, improving human welfare and raising living standards [41]. Hence, energy plays an equally central role along the dimensions of sustainable development as a key driver of multilateral growth. The relationship between RE and sustainability can be reviewed as a hierarchy of goals and constraints that involve both global and regional or local considerations. SD was tightly coupled with climate change and REs deliver a major contribution towards mitigation of environmental impacts.

The authors develop eight indicators to follow energy sustainability in Iran (similar to SEW reports). There are no official annual reports to pursue sustainable development index. Moreover, Iran's statistical flow in sustainability measures is so poor. Nevertheless, this section is intended to provide a general overview of Iran's energy sustainability state.

CO_2 emissions: There is a great concern about global warming due to increasing concentrations of greenhouse gases in the atmosphere [13]. Greenhouse gases and CO_2 in particular, have risen to the top of the list of the energy sector's environmental impacts, as the source of human-made climate change. The main CO_2 emissions are caused by combustion of fossil fuels to provide energy in transportation sectors.

Iran's CO_2 emission is considerable and placed the country among the top ten emitting countries [42]. Due to the fact that Iran is one of the biggest producers of oil and gas in the world, so that the most of CO_2 produced is related to these sources of energy which are used in diverse industrial section such as power plants [43]. As is illustrated in Fig. 2, Iran's CO_2 emissions indicator is ever increasing.

Ambient Pollutants: There are three anthropogenic activities which are known as the major sources of air pollution:

- Stationary sources (use of fossil fuels in industries and thermal power plants)
- Mobile sources (vehicles)
- In-door sources (burning of bio-mass) [26]. In addition, air pollution may occur in consequence of CO_2, SO_2 and NO_2 emissions due to fossil fuel burning process. It has been deteriorated all over the country, especially in the urban areas.

Air pollution in Iran's large cities such as Tehran, Isfahan and Tabriz is the most critical energy-related pollutant. The rapid rate of urbanization due to rural

Table 2: Status of rural electrification in Iran [48].

	Total rural areas				Electrified rural area by ended up 2011			
Group	Rural	Households	The average number of households in each rural	Share of households	Rural	Households	Percentage of electrified rural area	Percentage of electrified rural households
Rural areas with up to 20 households	41636	4123101	99	96.6	41636	4123101	100.0	100.0
Rural areas with less than 20 households	14093	146121	10	3.4	12480	138022	88.6	94.5
Sum	55729	4269222	77	100	54116	4261123	97.1	99.8

migration to metropolitan areas, the rapid growth of vehicles and the associated consumption of petroleum, the use of older, poor burning vehicles, also poor public transportation system, the low price of petroleum products and a weak urban management are all these factors causing to generate serious pollution [27].

Households with Access to Electricity: Electricity is sole source of energy and it has improved the quality of public lives around the world [45]. Consumers, including industry, rely on affordable, dependable electrical energy [46]. Beyond the basic use of electricity in households for lighting, radios, communications and basic home appliances, the application of electricity to activities that might bring economic development through productive enterprises and agricultural development can be an important engine of growth [47]. On the other hand, access to electricity, is a crucial component to poverty reduction and has great benefits on people's lives in rural areas of the developing countries.

As expressed in the Table 2, the overall task of Iran's rural electrification has been successful. By 2011, 100% of the villages with over 20 families and 88.6% of villages with less than 20 families have been electrified. Hence, by 2011, the all of cities and 97.1% of the villages have been accessed to electricity.

Investment on Clean Energy: Clean energy is created through clean, harmless and non-polluting methods and has less impact on environment than other conventional energy sources. It creates a negligible amount of carbon dioxide and its use can reduce pollution that contributes in reduction of global warming. On the other hand, most of the renewable energy sources could be classified in the clean energies category. In recent years, investments on renewable energy sources have significantly grown.

Iran has a high potential of renewable energy sources. Therefore, the utilization of these potential sources must be optimized. In May 2012, Iranian government officials approved the allocation of €500 million from the €35 billion National Development Fund for renewable energy projects [49]. Results of study concerning the possible renewable energy utilization in Iran showed a future target of 20,000MW is feasible in year 2025. Of course, 10 percent renewable energy contribution in only 15 years needs determination, data acquisition, technology capacity achievements and highly detailed planning and execution. For this purpose crucial key elements of a national program should be defined [17].

Energy Trade: Energy trade means both buying and selling of energy commodities such as oil, coal, natural gas and electricity from where they are produced to where they are needed. Energy products are the main elements of world trade. According to statistics from the World Trade Organization (2009), world merchandise exports grew at an average annual rate of 12% between 2000 and 2008 [50].

Iran's economy relies highly on its energy exports. Most of Iran's exports are oil and natural gas. In 2010, petroleum constituted 80 percent of all exports from Iran [51]. Considering that the ratio of oil reserves to oil production amount in Iran is about 87 years and that up to the next 30 years, much of the energy of present buyers of oil will be supplied from renewable energies, it can be concluded that there is not a long time to convert oil wealth to a sustainable wealth. So, higher production of crude oil and its exports is quite economical. The best approach to Iran is development of domestic energy and non-oil economy and exporting more oil. Oil export revenues can be spent in long-term investment inside and outside the country. Industrial investment and technology promotion are the best strategy to use the oil capital, similar approach like Norway which develops its national economy with the profits of its oil revenues. Table 3 shows the balance of trade in Iran.

Public Sector Investment: The government shoulders the majority of the investment burden in energy sectors and has an important role to play in stimulating investment in the nation's energy infrastructure. Some of the organizations related to Iran's public energy sector are explained here briefly:

Ministry of Energy is the main organ of the government in charge of policy-making and management of generation and transmission of electricity.

Table 3: Iran's balance of trade [52].

Description/ Year	1990	1995	2000	2005	2011
Natural gas balance of trade (bcm)	-1.93	0	3.28	0.44	1.34
Oil products balance of trade (Mt)	2.71	-6.302	-16.724	-9.51	-3.23
Crude oil, NGL balance of trade (Mt)	-110	-121.02	-122.42	-132.50	-123.11
Coal and lignite balance of trade (Mt)	0.22	0.46	0.97	0.94	0.81

Table 4: Energy intensity of GDP at constant purchasing power parities (koe/$2005p) [52].

Year	Iran	South Africa	Japan	China	Canada	Norway	Venezuela
1990	0.2	0.341	0.136	0.722	0.278	0.154	0.242
2000	0.265	0.344	0.143	0.328	0.251	0.132	0.254
2011	0.277	0.299	0.121	0.266	0.216	0.139	0.22

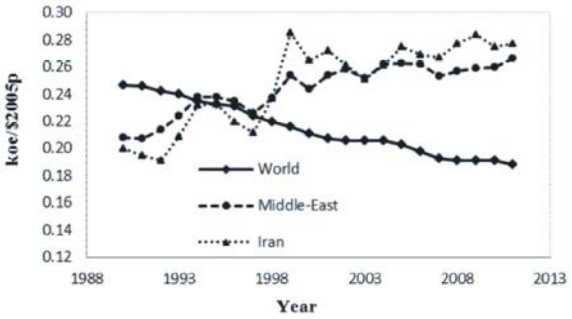

Fig. 3: Energy intensity trends by region [52]

Iran Renewable Energy Organization (SUNA): SUNA was established in 1995 in order to access updated information and technology related to renewable energies. Since 2003, it's responsible for the development of renewable energies (solar, wind, geothermal, hydrogen and biomass).

Ministry of Petroleum (MOP) is responsible for exploration, extraction, refining, exploitation and exportation of oil and gas products in Iran. Before the Ministry's establishment, the authority for all petroleum activities in charge was the National Iranian Oil Company.

According to the necessity of using renewable energies in Iran, the requirement in this regard and align with Article 44 of the Islamic Republic of Iran's Constitution, the Iranian Renewable Energy Organization (SUNA) has set participation and support attraction of Nongovernmental sector's investment as one of its major missions. Private sectors had already signed contracts to build more than 600 MW of biomass systems and 500 MW of modern wind energy developments. Based on SUNA remarks the private sector has submitted a proposal for generation of 3000 MW.

Energy Intensity: Energy intensity, the energy consumption per GDP output, is a good measure of the energy efficiency of a nation's economy. It is one of the important indicators of human development and progress for a country. Many factors such as mass transportation, fuel economy of vehicles, energy rationing and energy subsidies may influence the overall energy intensity of a nation.

Iran has one of the highest levels of energy intensity (i.e. the energy cost for producing each gross domestic production unit) in the world [53]. Fig. 3 illustrates the energy intensity in Iran and the world. As is illustrated, the energy intensity in Iran is almost as high as the Middle East region. Comparison of energy intensity between some countries is expressed in Table 4.

Deployment of Renewable Energy: In the face of growing worldwide concern about the effects of climate change and the need to ensure global energy security, most countries have begun to realize that the need for renewable energy sources will be as vital as ever. Iran has large solar, wind, hydroelectric and geothermal sources, but due to the presence of the vast oil and gas sources, renewable energies in Iran have been disregarded for a long time.

The studies and analysis conducted in the field of wind energy potential estimation in Iran have indicated that only in 26 regions (including more than 45 suitable sites) the nominal capacity of the sites is around 6,500 MW, considering a general efficiency of 33%, whereas the total nominal capacity of power plants is 60,000 MW (currently). In the field of solar energy, there are 11 projects pertaining to solar energy which are being utilized or carried out by the Ministry of Energy (Iran). The total solar electricity generation in 2004 was 14.02 MW. This rate has reached 67 MW by the end of 2010. At present, two geothermal projects are being constructed in Ardabil province. In 2010, about 50% of Meshkinshahr geothermal power plant project is completed and the package construction project in Ardabil succeeded by 32%. The construction of these two projects started, since

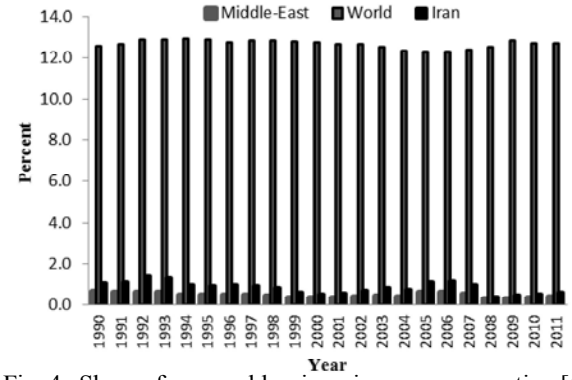

Fig. 4: Share of renewables in primary consumption [52]

2005. Due to the financial hardship in the Fourth Development Program, these projects were extended until the end of the Fifth Program. The nominal capacity of biogas power plants in Iran is 1.86 MW, the total practical capacity is 1.665 MW and gross generation is 5,967 GW/h. According to, Strategy Document of Fuel Cell Technology Development (approved by cabinet 2004), Iran has had good progress in fuel cell projects. In 2011, renewable energy contributed 0.61 % of Iran's total primary energy consumption, see Fig 4.

Fundamental Challenges about Development of Iran's Renewable Energy: Iran's specific geographical location provides high potential in the field of renewable energies, while accessible rich sources of oil and gas is an important challenge on pursuit of renewable energy development. The lack of development process in the field of utilizing renewable energy is evidently resulted, if one's compare the process in Iran and the world.

There are some barriers for development of renewable energies in Iran, which the most important are discussed as the followings:

- The major barrier for renewable energy development is the high subsidized energy that supplied by the government.
- Underdevelopment of technological capabilities for renewable energies.
- Inadequacy of specialists who are skilled in the field of renewable energies.
- Lack of renewable energy courses to inspire students to enter this field.
- Poor knowledge about the importance of energy and inadequate advertisement by the government could result in less motivation by energy users and consequently the application of renewable energies could not gain significant rate.
- Insufficient funds to conduct projects.
- Slow process of contracting.
- Lack of sufficient and effective planning in this field by executive section.
- Insufficient legislative support and improper management.

Policy Framework Requirements for Renewable Energy Development: Although Iran has rich reserves of oil and gas, it should not only rely on these resources and should take policies to develop alternative sources of energy. By taking into account, Iran has great potential in renewable energies and also its scheme towards actualizing the prices of energy carriers and with the help of designing a flexible and dynamic structure and removing the existing obstacles, it is necessary to analyze the infrastructures, policies and administrative structures in the field of renewable energies in the country to accelerate their development [16]. As mentioned earlier, there were some barriers for development of renewable energies in Iran. In this section some policies to resolve the problem are suggested.

Social acceptance of renewable energy for growth and development of this energy is very important. The government must do a lot of effort to increase public awareness of the benefits and advantages of these energy sources.

A successful energy policy should improve the living standards of people who will use it. Undoubtedly, by increasing technological capabilities, industrial development and social welfare will be improved.

By 2009, Iran was the largest provider of fuel subsidies in the world [54]. It's the major barrier for renewable energy development in Iran. The increase of energy carrier's prices with the start of targeted subsidies plan in Iran has made the main energy consumers, such as leading consumers and Industries to manage their energy resources in such a way to use solar energy for the production of electricity [55]. Implementations of this plan will bring more attention to the employment of renewable energies.

Domestic universities and research centers play an important role in transferring modern technologies to their countries. Introducing new courses of renewable energy can help to educate managers and engineers in this field. New undergraduate and postgraduate courses can provide skilled manpower and expertise to design, build and implement renewable energy systems. Moreover, to inspire young students to enter this field, renewable energy courses should offer in first degrees.

However, the electricity demand growth, future perspective of the industry, constraints of governmental financial resources and most importantly, marginal growth in renewable energy source projects in Iran has made the contribution of the private sector an undeniable necessity [56]. The government must support and encourage the private sector in the field of renewable energies, for instance, guarantee to purchase the electricity produced by the private sector from renewable energy power plants.

CONCLUSION

Iran has a great potential in terms of renewable energies. The promotion of renewable energy plays a central role in construction plans for the institutionalization of a sustainable policy concept. The authors develop eight indicators to follow energy sustainability in Iran. Currently Iran's energy system is far from sustainable. While Iran's access to electricity indicator is nearly sustainable, the most indicators, such as CO_2 emissions, ambient pollutants and energy intensity are increasingly unsustainable. Furthermore, the share of renewable energy in Iran's energy basket is low. Table 5 shows whether each indicator is improving or deteriorating. The following summary is provided for each indicator to show some bold signals in the energy sustainability state in Iran.

- CO_2 emissions: Iran's CO_2 emission is considerable and placed the country among the top ten emitting countries.
- Ambient pollutants: Air pollution in Iran's large cities such as Tehran, Isfahan and Tabriz is the most critical energy-related pollutant.
- Households with access to electricity: By 2011, 100% of the villages with over 20 families and 88.6% of villages with less than 20 families have been electrified.
- Investment in Clean Energy: In May 2012, Iranian government top officials approved the allocation of €500 million from the €35 billion National Development Fund for renewable energy projects.
- Energy Trade: Iran's economy relies highly on its energy exports. The most of Iran's exports are oil and natural gas. In 2010, petroleum constituted 80 percent of all exports from Iran.
- Public sector investment: Private sectors had already signed contracts to build more than 600 MW of biomass systems and 500 MW of new wind energy developments.

Table 5: The state of Iran's indicators

Indicator	Improving	Deteriorating
CO_2 emissions		✓
Ambient pollutants		✓
Households with access to electricity	✓	
Investment in Clean Energy	✓	
Energy Trade	✓	
Public sector investment	✓	
Energy intensity		✓
Deployment of renewable energy	✓	

- Energy intensity: The energy intensity in Iran is almost as high as the Middle East region.
- Deployment of renewable energy: According to the Iran's twenty-year documentation, by 2025 Iran is assumed to produce 10% of its required electricity from renewable sources.

The results of present research shows that Iran's energy policy for mitigation of environmental impact and promote sustainable consumption has not yet been realized (like most developing countries). Hence, some major actions are required as follows:

- Changing energy consumption paradigms and elevating public awareness.
- Make public and government officials more and more sensitive to environmental issues.
- Make some practical rules and regulations to help private sector manufactures and researchers involved in the REs projects.
- Policies to reduce greenhouse gas emissions in the industry.
- Allocation of a part of public resources in the annual budget to guarantee the purchase of electricity generated from renewable energies.
- Determination of a percentage of the consumed electricity of subscribers (e.g. one percent) and calculation of its price in the subscriber's bill using guaranteed prices of renewable energies.
- Create plans to improve energy efficiency.
- Implement effective support policies for REs development and utilization.
- Establish policies and laws to improve REs market.

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Persian Abstract

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چکیده

عواملی نظیر محدودیت منابع انرژی‌های فسیلی، اثرات زیان بار آن‌ها روی محیط زیست، قیمت‌های انرژی‌های فسیلی، نزاع سیاسی و اثرات آن بر عرضه انرژی پایدار، موجب گردیده‌اند که بسیاری از سیاست‌مداران و متخصصین انرژی و محیط‌زیست به سمت توسعه ساختارهای مدرنی به منظور تضمین عرضه انرژی، حفاظت از محیط‌زیست و بهبود کارایی سیستم‌های انرژی بروند. از این جهت، بیش‌تر کشورها متوجه این حقیقت شده‌اند که پایداری در حوزه‌ی مصرف و تولید انرژی به شدت حیاتی می‌باشد. بنابراین، پیشرفت در جهت دستیابی به پایداری بسیار ضروری می‌باشد. هدف اول این مقاله این است که توسعه پایدار در بخش انرژی ایران براساس شاخص‌های موسسه بین‌المللی Helio مورد بررسی قرار گیرد. با توجه به چارچوب‌های این موسسه، ایران در شاخص دسترسی به الکتریسیته به پایداری بسیار نزدیک می‌باشد. در حال حاضر ایران وضعیت مناسبی در مورد شاخص‌های انتشار دی‌اکسیدکربن و شدت انرژی ندارد. بخش خصوصی ایران قراردادی مبنی بر ساخت بیش از ۶۰۰ مگاوات از سیستمهای زیست-توده و ۵۰۰ مگاوات از انرژیهای بادی تنظیم نموده است. بنابر اظهارات سازمان انرژی‌های نو ایران (سانا) بخش خصوصی طرح تحقیقی مبنی بر تولید ۳۰۰۰ مگاوات، ارائه نموده است .هدف دوم این مقاله، بررسی چالش‌های اساسی در توسعه انرژی تجدیدپذیر و ارائه سیاست‌های مورد نیاز جهت دست‌یابی ایران به پایداری در حوزه انرژی می‌باشد.