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REVIEW

Iran's energy scenarios on a 20-year vision

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Abstract With the heightened awareness of global environmental issues of greenhouse gas emissions by fossil fuels as non-renewable energy resources, the application of renewable energies (REs) has emerged as one of the most significant policies in most of the countries throughout the world. Although Iran is blessed with high potential of RE resources such as solar, wind, and geothermal, development of such resources, however, has been neglected due to the various reasons. Considering the long time needed to develop and deploy RE resources, a long-term planning is required in this area. Therefore, applying the scenario planning method, this research develops four scenarios in Iran's 2025 vision, through a combination of the changes in energy consumption and RE generation: *green path*, *standardization*, *fossil energy,* and *non-targeted subsidy*. Developed scenarios are then compared with the government plan for utilizing REs in 10 % of total electric power generation in a 20-year vision. Results indicate that *standardization* and *fossil energy* are the most probable scenarios. *Green path* is the most optimistic scenario for the country, suggesting the goal of producing 10 % of total electricity share through REs could be achievable by 2025. And the *non-targeted subsidy* is the most pessimistic and unexpected scenario for the country.

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Introduction

Energy is central to improved social and economic well-being and is indispensable to most industrial and commercial wealth generations. It is the main factor for relieving poverty, improving human welfare, and raising living standards (Dong et al. 2013). Energy has a fundamental role in moving toward sustainable development and social actualization in modern age.

In attaining sustainable development, increasing the energy efficiencies of processes utilizing sustainable energy resources plays an important role (Hepbasli 2010). Renewable energies are produced using harmless techniques in which they have less destructive effects on the environment compared with the other types of energy. Therefore, REs have an essential role in moving toward sustainable development. With increasing concerns over global warming and climate change and also to ensure world energy security, several countries have begun to realize that the need for sustainability in energy production and consumption is increasingly vital.

Located in the Middle East, Iran holds the world's second largest natural gas reserves and also the OPEC's second largest supply of oil (Fadai et al. 2011). The country's economy is heavily dependent on energy exports, in a way that the majority of Iran's exports are oil and natural gas. In 2010, only petroleum constituted 80 % of all exports from Iran (Economy watch 2010). Iran also has a high potential of REs, such as hydropower, wind, solar, geothermal, and wave energies. Hence, the use of these resources is clearly necessary to reduce consumption rate.

These energies, however, have long been neglected due to several reasons such as abundant oil and natural gas reserves. Unfortunately, the share of renewable resources in Iran's energy basket is not impressive. In 2011, only 0.61 % of total energy consumption in Iran was produced by renewable resources (Enerdata 2012).

Scenario can be defined as a proper understanding of how the world may change in the future, how to recognize these changes as they happen, and what to do if these change occur. A scenario embodies a plausible view or perception of the future in a given year linked to conditions in the present via an internally consistent sequence of events. It could be described as a roadmap from the present to the future (Four scenes 2014). "Scenarios" have been an important method of studying the future since 1960s (Wang and Lan 2007). Scenario planning method is common among the analyzers and is highly applied by them, mainly because it is capable of a long-term prediction, particularly when an uncertainty has surrounded a problem. Instead of imagining a specified future, the method considers several probable futures, which is more realistic. Each of these futures has its own primary assumptions though.

Iran has a high potential of RE resources, and despite large oil and gas production capacities and reserves, relying on just fossil fuels would be arguable given several factors like limited fossil fuel resources, environmental degradation, rising fossil fuel prices, political disputes, and their effects on supplying sustainable energy. Therefore, there is an indispensable need to set a general policy in energy sector as well as an integrated plan to a wider use of REs. Since the development of such energies requires high technologies (without visible short-term progress), a general, long-term strategy seems vital. Long-term predictions are also required in order to investigate the future. Thus, with the high capability of scenario planning in long-term prediction in an uncertain condition, this technique is applied in this research in order to investigate the probable future trends of Iran's status in energy consumption in general as well as production and utilization of REs.

The framework of this research is as the following: Sect. 2 exhibits a comprehensive literature review of research related to our work. Section 3 describes the concepts and importance of scenario planning. Energy consumption and RE production as the two main parameters in scenario developing are discussed in Sect. 4. After establishing the model, Sect. 5 proposes four energy scenarios for Iran by combining the trend variations of these two parameters. Section 6 conducts an analysis and comparison of the developed scenarios with the state national plan. And concluding remarks are summarized in Sect. 7.

Literature review

Policy makers have long sought to understand the environments and the plausible future in which they operate. Several methodologies such as trend extrapolation, simulations and games, technological forecasting, Delphi polls of experts, and futures wheels have surfaced to help governments and policy makers achieve such alignment. Scenario planning is another method that has gained increased attention during the last 20 years as an effective tool for examining future uncertainties and investigating assumptions in organizations (Pillkahn 2008). It has been applied in all sorts of contexts, from strategic planning in companies, municipal and land-use planning, and political consultancy to global scenarios concerning the future of the climate (Kosow and Gabner 2008).

Energy is another context that has long been in the spotlight of policy makers and scenario planners either in local, national, or international level. Various researches have been carried out in different branches of energy using scenario planning. Some researchers focused on one area: Rachmatullah et al. (2007) used scenario planning to devise a long-term electricity supply plan for the Java–Madura–Bali electricity system in Indonesia. They found that the scenario planning method could save up to US$3.5 billion over a 15-year period if the method was applied right at the beginning of the period. Logan et al. (2013) modeled two alternative scenarios for the US natural gas sector using a high-resolution capacity expansion model. Or Paltsev (2014) explored the long-term (up to 2050) scenarios of Russian natural gas exports to Europe and Asia using the MIT Emissions Prediction and Policy Analysis (EPPA) model.

Some researches were concentrated on different aspects of energy: Wang et al. (2013) considered energy efficiency and productivity to develop three production scenarios, namely energy conservation (EC), energy conservation and emission reduction (ECER), and energy conservation, emission reduction and economic growth (ECEREG) to assess China's energy efficiency and productivity growth during the period of Eleventh Five-Year Plan. Vuuren et al. (2003) developed a set of energy and emission scenarios for China between 1995 and 2100, based on the global baseline scenarios published by IPCC. The focus was on possible baseline developments and available options to mitigate emissions. To apply a systematic and proven process of technology portfolio planning in Taiwan, Chen et al. (2009) constructed three scenarios ("Season in the Sun," "More Desire than Energy," and "Castle in the Air") that encompass future uncertainties in the relationships between the technology alternatives and the decision values. Analysis of other long-term trends such as energy security, economics, energy supply and demand, geopolitical shifts, and social change has also been considered by scenario planners (Renn 2003; Guerra et al. 2014; Jiang and Hu 2006; Jewell et al. 2014; Bilgin 2011; Criqui and Mima 2012; Grave et al. 2012; Weldegiorgis and Franks 2014; Fortes et al. 2014; Tanatvanit and Limmeechokchai 2003).

While there are researches that are focused completely on one parameter, many literatures consider various factors involved in different types of energy. Silberglitt et al. (2003) reviewed a collection of recent energy scenarios from a policy and planning perspective and compared these scenarios quantitatively with respect to US energy consumption, energy efficiency, and carbon content of the fuel mix in 2020. In another research, Ghanadan and Koomey (2005) developed and analyzed four energy scenarios for California that are both exploratory and quantitative. Future energy consumption, composition of electricity generation, energy diversity, and greenhouse gas emissions were analyzed for each scenario through 2035. Geem and Roper (2009) proposed an artificial neural network model (a structure with feed-forward multilayer perceptron, error back-propagation algorithm, momentum process, and scaled data) to efficiently estimate the energy demand for South Korea. Their model has four independent variables, such as gross domestic product (GDP), population, import, and export amounts. These variables were estimated with four scenarios to predict energy demand in 2025.

The development of scenarios to explore RE and low carbon futures has been widely applied (Fortes et al. 2014), as policy makers seek to investigate and probe all the possible future of expanding RE deployment. A scenario technique for development of small-scale deep geothermal power in Germany has been carried out by Purkus and Barth (2011). They explored the factors driving this development, and the role geothermal power production could play in the future of the German electricity market. Fernandes and Ferreira (2014) strived to address the topic of RE scenarios for the electricity sector, analyzing different possible future strategies for the Portuguese system. Or Scarlat et al. (2013) aimed to quantify the impact of 2020 bioenergy targets on the land use in the European Union, based on the projections of the National Renewable Action Plans in four scenarios. In this study, four different scenarios for RE development in Iran are introduced, and the possibility of achieving 10 % REs systems is being debated. There were studies that were concentrated on fossil fuels in Iran. For instance, Azadi and Yarmohammad (2011) analyzed Iran's oil export capacity and the factors affecting it. Or in a research by Kiani and Pourfakhraei (2010), a system dynamic model was presented, which considers the feedback between supply, demand, and oil revenue of the existing system in Iran considering different sectors of the economy. Three scenarios, which show the worst, base, and ideal cases, were considered to find future trends of major variables. The scenarios of this study investigate Iran's energy with focus on REs production that is both exploratory and qualitative. Two main parameters (energy consumption and RE production) are considered as they have direct impact on each other. And other factors influencing energy production and consumption like subsidy reform, standardization, privatization, and social impact are discussed in scenarios.

Besides, methods applied in this study have widely been used in future studies. Cross-impact analysis (CIA) introduced in Sect. 3 is one of the most commonly used techniques for generating and analyzing scenarios (Bañuls and Salmeron 2007a, b; Bañuls et al. 2010). It has resurged as a powerful tool for forecasting the occurrence or not of a set of interrelated events (Cho and Kwom 2004; Weimer-Jehle 2006). Visualization on the other hand, as one of the judgmental techniques, is used to build the scenarios. Researches like Abbaszadeh et al. (2013) have used this scenario technique with the aim of reaching novel insights and revelations.

Scenario analysis

There are complicated and mutual connections and relationships between the factors in an interconnected world on which business success is dependant. There is no way to model these behaviors accurately as traditional methods for strategic planning based on complicated predictions seem to be overwhelming. In such condition, scenarios can represent a proper path for long-range future planning.

There is no unique definition for scenario or scenario planning. Various definitions of this term have been presented by the researchers in this area:

- An internally consistent view of what the future might turn out to be (Porter 1985);
- A tool [for] ordering one's perceptions about alternative future environments in which one's decision might be played out right (Schwartz 1991);
- That part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future (Ringland 1998);
- A disciplined method for imaging possible futures in which organizational decisions may be played out (Shoemaker 1995).

Scenarios must be judged based on their ability to help those who make policies at present, not after they would prove to be wrong or right. Concisely, the process of scenario planning offers many major advantages, including:

- Helping firms deal with uncertainty and evolutionary change in their surrounding environment through challenging the assumptions of managers about their environment (Walsh 2005);
- Helping managers to define the choices and increase their ability to select and accelerate their decision making (Alessandri et al. 2004);
- With investigating the strategic options for different scenarios, managers ask: "what decision should be made under these circumstances?" or "what are the effects of this event?". In fact, they implement a sensitivity analysis with respect to the probable strategies (Van der 1996);
- It develops a stronger strategy compared with the traditional methods of strategic planning (Johnson and Scholes 2010);
- It increases the organizational intelligence and activity (Alessandri et al. 2004);
- It develops organizational learning (Dewulf and Schaaf 1998);
- It is an appropriate way to heighten the comparative advantages of the organization (Schwartz 1999).

Scenario mainly aims to enhance the quality of making future decisions; otherwise, it is nothing more than a trifling speculation (Wack 1985). Since the future is uncertain, today, most of the programmers and predictors refuse the idea that the planning should be based on the most probable image of the future. Instead, they believe a set of scenarios are essential to be applied in planning process. If these sets include a wide range of future probabilities and oppose their consequences, strong elements of plans would be extracted. It would also be possible to encounter the future with a higher level of certainty.

Energy has always been considered as the foundation of the development in any country. The significance of this state indicates that energy defines the main channel of global economic and political cycle. With an unprecedented expansion in energy usage around the world in recent decades, this key factor has entered into a new crisis cycle. Meanwhile, the analyzers and experts have continuously investigated the present trends and predicted the future. Considering global warming and carbon dioxide emissions, numerous researchers have warned the continuance of the present trend. Therefore, the need for long-term predictions in order to investigate the future is necessary more than ever. There are lots of prediction methods. Most of them are reliable for the few-year interval, though, as they can merely address short-term needs. Hence, methods with a wider range of prediction (50 or even 100 years) seem useful and beneficial. Because of imagining several possible futures in scenario-based methods, this approach is more flexible about the continuous future changes. Thus, majority of the organizations apply this advantageous method, particularly when a macro-planning is considered. This important fact is understood about the energy sector by large companies and organizations. The huge budgets allocated annually to codify and update the reports on the future energy status are the aspects of this perception. International Energy Agency (IEA), World Energy Council (WEC), and Shell are among the big-spender organizations seeking to provide future scenarios.

Energy consumption and production in Iran

According to the simultaneous analysis of future RE generation and energy consumption, four scenarios can be obtained: green path, standardization, fossil energy, and non-targeted subsidy. The main characteristics of these scenarios are attained through the mixture of different situations of energy consumption and RE production. Before introducing the scenarios, the current status of these two parameters are discussed separately.

Energy consumption in Iran

High population growth and increasing standards of living for many people in developing countries are causing strong growth in energy demand. Figure 1 shows the world consumption of fuels by energy source, since 1965. As is shown, the global energy consumption has increased twofold in last forty years. This growth for energy is expected to increase substantially in the upcoming years. Better food supply, clean water, sanitation, health, education, and communication facilities are all as the motives to fulfill this strong desire. Energy producers are inevitably looking for more accessible and cheaper resources, and consumers

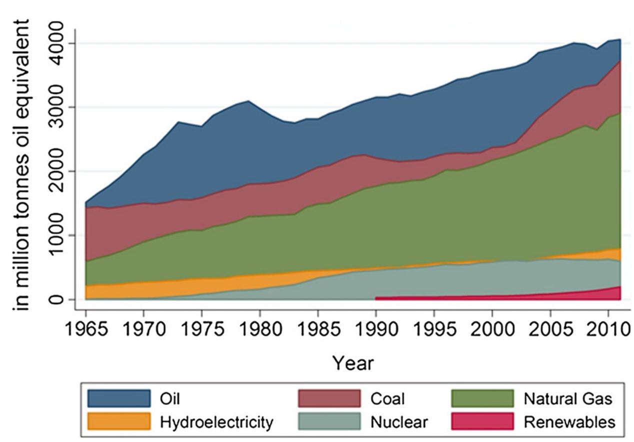

Fig. 1 World energy consumption (BP 2012)

have a common preference: quick access to lower-cost energy.

Having a comprehensive plan, most of the developed countries nowadays pay sustained attention to the energy sector with desire to forecast energy demand. Statistics signify that the need for energy has increased substantially during the last 30 years. The global energy consumption was equal to 3.3 Gtoe in 1960 and increased to 8.8 Gtoe in 1990 which indicates an annual average growth of 3.3 %, generally increased by 166 %. It is also predicted that this trend would increase to 14 Gtoe/year in 2020 (EIA 2010). These numbers clearly state that there will be a high level of energy consumption in the next decades.

An unimpressive high energy consumption in Iran is far from global standards. For instance, according to the statistics released by the Ministry of Energy and Ministry of petroleum in energy balance sheet (Ministry of Power 2009), for each 100,000 Toman wealth creation, Iran has consumed 2.3 barrels of petroleum in 2008, which highlights the wrong way of energy consumption in the country. As is shown in Fig. 2, Iran's energy consumption has increased dramatically in recent years.

Figure 3 shows energy consumption in Iran's major sectors. Residential sector continues to be the main energy consumer. Urban expansion, lack of proper implementation of laws, and extremely low-cost energy are the key drivers of energy consumption growth in this sector. Therefore, a strong national commitment along with more serious plans are required to control the energy consumption in this sector.

Transportation sector is another huge energy consumer sector faced with several barriers including: old vehicles with outdated technologies; lack of accessible public transportation; negative culture of using private cars for relatively short journeys among the different classes of society; and low-cost fuel. Energy consumption in this sector has continuously increased for the last 40 years (Fig. 4).

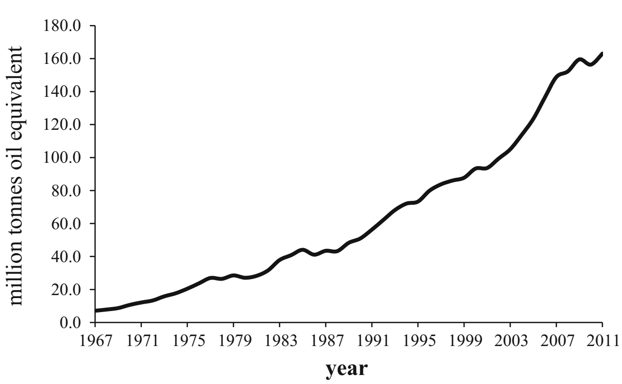

Fig. 2 Iran's total energy consumption (Ministry of Power 2012)

Energy consumption growth in recent years in industrial sector reflects the high natural gas consumption in this sector. With strategies emphasized in Iran's Third Development Plan in order to support production sectors such as funding mechanisms, providing financial resources in order to create new job opportunities, facilities grants, foreign finance, and using earning facilities in energy efficiency, this sector has enjoyed a higher and faster economic growth compared with other sectors. However, there is still a long way for more efficient energy consumption in Iran's industrial sector. The challenges of catching up with global patterns can be reasoned as follows: low energy efficiency; low domestic energy prices; not using new technologies; and improper utilization of worn-out machinery and industrial equipment. Figure 5 shows the trend of electrical energy consumption in this sector.

In other sectors such as agriculture, the growth rate of energy consumption is way higher than global standards as well. As is shown in Fig. 6, energy consumption in the agriculture sector is increasing.

Sadly, energy efficiency and energy savings are not seriously taken into consideration by current government policies yet. As shown in Fig. 7, there are significant energy subsidies in Iran. These keep prices for consumers

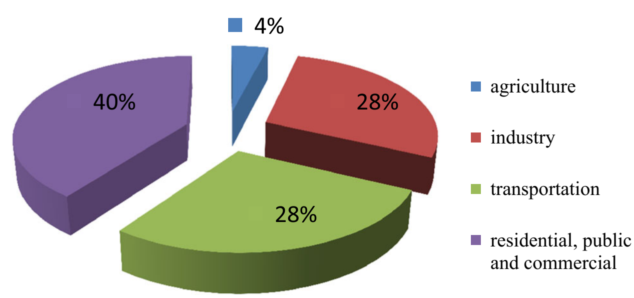

Fig. 3 Iran's energy consumption by sector, 2011 (IEEO-SABA 2014)

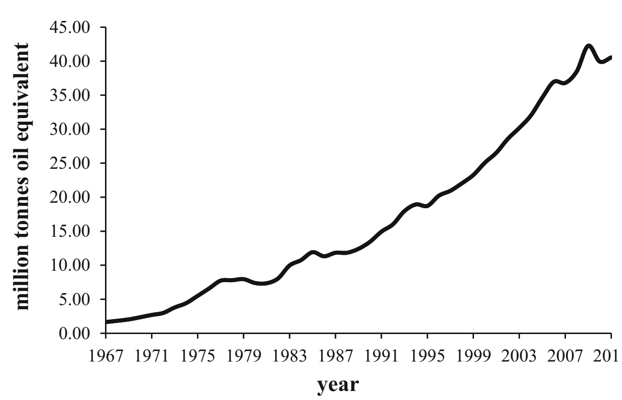

Fig. 4 Energy consumption for transportation in Iran (Ministry of Power 2012)

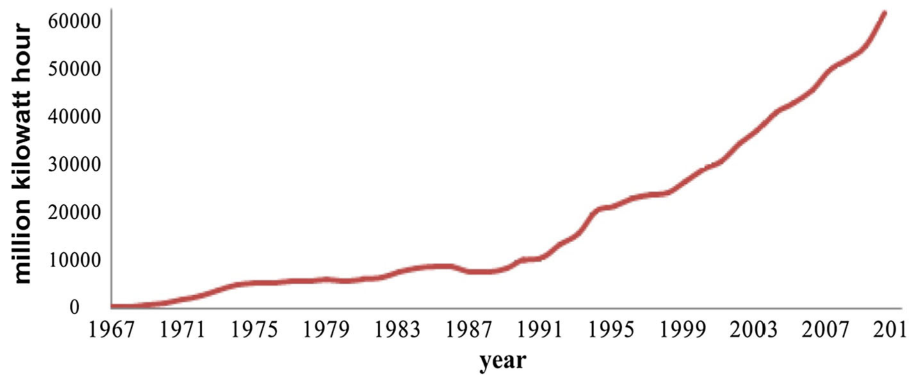

Fig. 5 Energy consumption in the industrial sector of Iran (IEEO-SABA 2014)

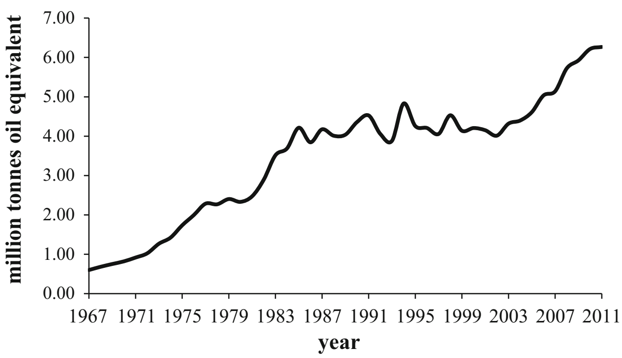

Fig. 6 Energy consumption in Iran's agriculture sector (Ministry of Power 2012)

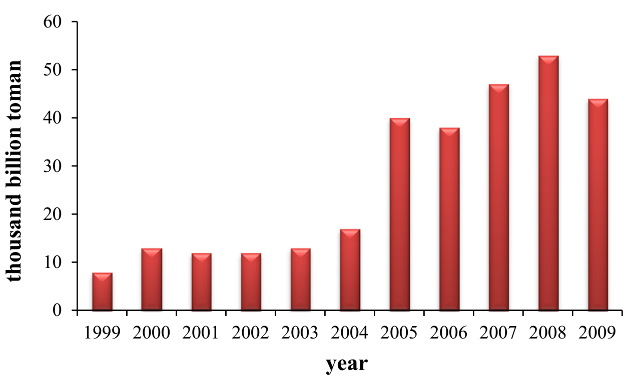

Fig. 7 Subsidies to the energy sector in Iran (Ministry of Power 2010)

below market levels, resulting in excess energy consumption as well as energy waste. In this regard, the "Iranian targeted subsidy plan" also known as the subsidy reform plan can act as an important driver to lead energy users to the lower consumption. Like reform implementation in neighbor countries in the previous years, Iran has started the reform plan in 2010 (Table 1). After the implementation of this plan, there have been certain positive signs of changes in energy price which affected the production and consumption rate as well as the social and cultural interactions on energy area. According to the subsidy reform plan set out in December 2010, the allocation of subsidies in all sectors has to be targeted by the end of 2015; so that energy costs reach about 90 % of regional energy prices and consequently results in the efficiency of energy use in the country (Tasnimnews 2013).

In the first phase of the subsidy reform, the authorities substantially increased the prices of all major petroleum products and natural gas, as well as electricity, water, and bread, with price increases by up to 4–20 times (IMF 2013). The phase envisaged direct assistance to enterprises to facilitate adjustment to the new price structure. In addition, the enterprises were to receive subsidized loans for the adoption of new, energy-saving technologies and credit lines to mitigate the impact of energy price increases on their production (Table 2).

However, despite the initial positive response of demand to price changes, the growth in consumption of subsidized products rebounded in 2012 as the price increases under the second phase of the reform were suspended, energy prices remained unchanged, and inflation and nominal incomes rose (Irandiplomacy 2014). This has resulted in delay of the second-phase implementation as the success rate of the reform will remain to be seen in the next few years.

Renewable energy production in Iran

Investments undertaken in alternative energies sector simply indicate that various countries around the world are intensely willing to secure the energy supply through renewable resources. The net electricity generation through RE resources in the world is shown in Fig. 8. The USA, China, Germany, and Spain are the pioneers of applying REs throughout the world.

In addition to the fossil fuels, Iran has a decent potential of renewable resources due to its geographical situation, which can be applied for electricity and heating. According to the experts, the solar atlas of Iran is among the best in the world. Solar energy map of the country is shown in Fig. 9.

Table 1 Iran and neighbors' energy subsidy reform episodes (IMF 2013)

Country	Energy product	Reform episode	Reform outcome	Reform impact	International Monetary Fund (IMF)-supported program during the reform episode	Conditionality on energy subsidy reform
Armenia	Electricity	Mid-1990s	Successful	Electricity sector financial deficit declined from 22 % of GDP in 1994 to zero after 2004	Yes	Yes
Iran	Fuel	2010	Partially successful	Growth in the consumption of petroleum products initially stabilized	No	–
Turkey	Electricity	1980s	Successful	Generated additional revenues for maintenance	Yes	Yes
	Fuel	1998	Successful	SOEs turned from net loss to net profitability	Yes	Yes
Yemen	Fuel	2005	Partially successful	Subsidies declined from 8.7 % of GDP in 2005 to 8.1 % in 2006	No	–
	Fuel	2010	Partially successful	Subsidies declined from 8.2 % of GDP in 2010 to 7.4 % in 2011	Yes	Yes

Table 2 Reforms and institutional arrangements in Iran and its neighbors to enhance small- and medium-sized enterprises access to Finance (IMF 2013)

Country	Legal and credit information infrastructure					Other	
	Registering property	Credit information	Protecting investors	Enforcing contracts	Resolving insolvency	Credit guarantee	Financial support programs
Armenia		✔	✔	✔	✔		✔
Azerbaijan	✔	✔	✔	✔			
Iran	✔		✔	✔			
Iraq							✔
Qatar		✔		✔			✔
Saudi Arabia	✔	✔	✔		✔	✔	✔
United Arab Emirates	✔	✔	✔				✔
Yemen		✔					

The solar energy in Iran varies from 2.8 kWh/m^2 in day in the north to 5.4 kWh/m^2 in day in the south (IIES 2010). Figure 10 shows the total solar electricity generation in Iran from 2005 until 2012. Using only 1 % (15,510 km^2) in Iran can not only fulfill the present annual energy requirements at home, but can as an equal amount be exported to other countries too (Ghorashi and Rahimi 2011).

Iran has high potentials to exploit wind power as well. The total wind electricity production between 2005 and 2012 is displayed in Fig. 11. Blessed with mountains and coasts such as Persian Gulf Coast, the country is also capable of exploiting this type of energy. Besides, Iran possess various tropical wind flows such as the flow from Central Asia during winters and Indian Ocean during summers, western flow from Atlantic Ocean and Mediterranean Sea during winters, and the northwestern flow during summers (Ghorashi and Rahimi 2011). Situation of wind power station in several provinces in Iran is indicated in Table 3. Moreover, several regions have been spotted by the experts in recent years, which are suitable for installation of wind turbines.

The country also has a high capability in other types of renewables. For instance, since Iran is located on the global geothermal belt, it can be considered among the prevalent countries having geothermal energy (Atabi 2004). Table 4 shows the geothermal potential regions in Iran and their areas (Yousefi et al. 2007). Iran has substantial geothermal potential in the north and northern provinces, and there are several hot water springs, the temperature of some of which reaches to 85 °C (Ghobadian et al. 2009). Potential areas of geothermal resources in Iran are shown in Fig. 12. These areas are ranked in order of importance.

According to the CEO of Renewable Energy Organization of Iran, right now, about 300,000, MWh RE is

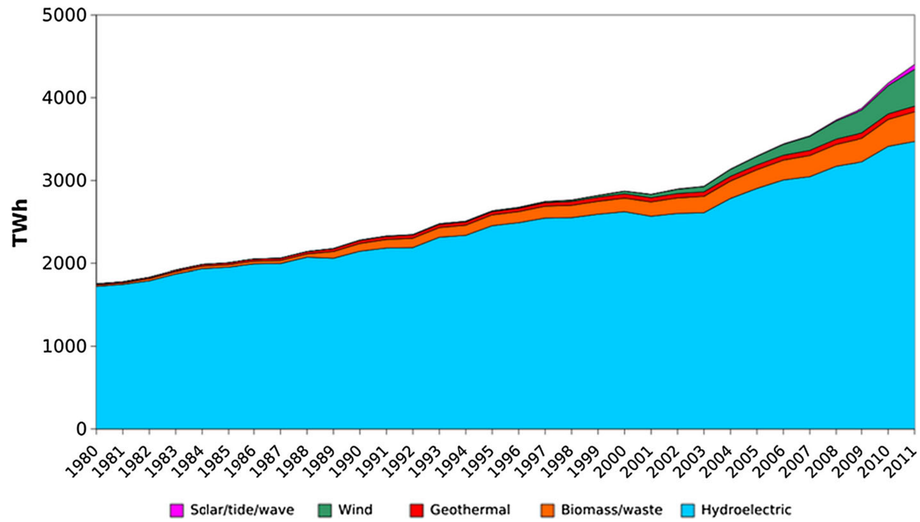

Fig. 8 Electricity generation from RE in the world (EIA 2012)

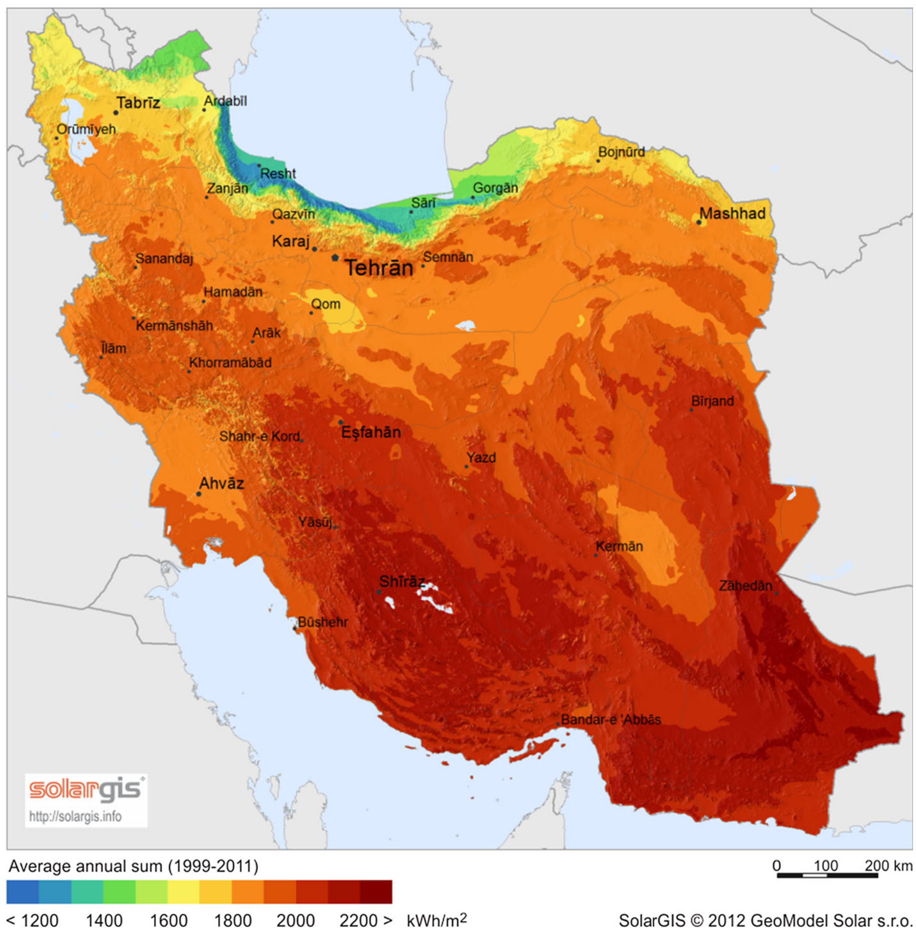

Fig. 9 Iran's solar energy map (SolarGIS 2014)

annually produced in Iran, which should increase up to 10 % of total electric power generation in the 20-year vision (Tavanir 2012). Wind and solar energies are more prevalent among the alternative energies, and considering high capacities in generation of solar energy, certain facilities have been directed to this area.

High cost of REs is the main drawback of using alternative energies in Iran, as gas and electricity are much lower than energies produced through renewable resources. Should the price of subsidized fuels like gas and petroleum increase up to their real price gradually, a balanced situation of the prices of alternative and other types of energies could be expected, in which a fair contest can be formed among various sorts of energy in order to optimize the energy basket of the country.

Considering the rise in electricity demand ratio, the future vision of industry, the limited financial resources of the government, and most importantly, the side growth of RE projects in Iran, the need for participation of the private sector is inevitable. Since the general policies of article 44 have prevented the government from investing in developing power stations, it can only participate through supporting the private sector and ensuring the purchase of the generated electricity. Development of RE power plants through this sector is indicated in Table 5. There are plenty of issues resulting lack of interest from the private sectors to enter this area, including: the existing subsidy system and lack of liquidity and credit facilities provided by banks. These factors have presently prevented the private investors from entering into this market.

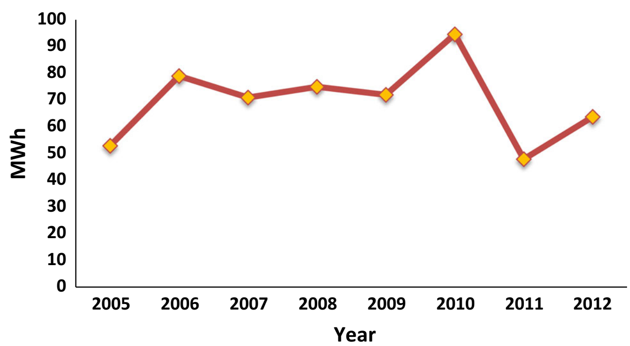

Fig. 10 Total solar electric generation in Iran, 2005–2012 (Ministry of Power 2013)

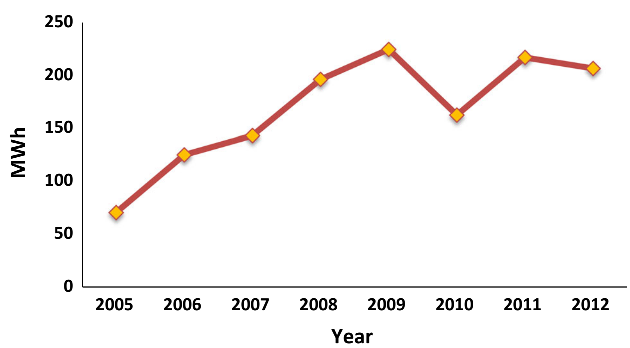

Fig. 11 Total wind electricity production in Iran, 2005–2012 (Ministry of Power 2013)

Table 4 Geothermal potential regions in Iran and their areas (Turcotte and Schubert 2002; Nejat et al. 2013)

Geothermal area	Province	Area (km^2)
Sabalan	Ardebil	13,037
Damavand	Tehran	4648
Khoy–Maku	Azerbaijan–Gharbi	3257
Sahand	Azerbaijan–Sharghi	3174
Bazman	Sistan and Baloochestan	8356
Taftan	Sistan and Baloochestan	4310
Tabas–Ferdoos	Khorasan–Jonoobi	46,628
Khour	Esfahan	2334
Tekab–Hashtrood	Azerbaijan–Gharbi	4639
Mahallat–Esfahan	Esfahan–Markazi	13,648
Zanjan	Zanjan	3285
Avaj	Hamadan	4283
Kashmar	Khorasan–Markazi	7107
Ramsar	Gilan	5532
Amol	Mazandaran	1697
Baft	Kerman	11,525
Minab–Bandarabbas	Khorasan	3191
Lar–Bastak	Khorasan	4191

Table 3 Location of wind power plant projects in Iran, 2012 (Ministry of Power 2013)

Province	In operation		Observation and executive	Total	
	No. of turbines	Nominal capacity (KW)	Capacity (KW)	No. of turbines	Nominal capacity (KW)
Gilan	128	72,460	26,940	128	99,400
Qazvin	–	–	60,000	–	–
Khorasan	43	28,380	–	43	28,380
East azerbaijan	4	1990	–	4	1990
Sistan and Baluchestan	1	660	–	1	660
Fars	1	660	–	1	660
Khuzestan	1	660	–	1	660
Isfahan	1	660	–	1	660
Ardabil	1	660	–	1	660
Total	180	106,130	26,940	180	133,070

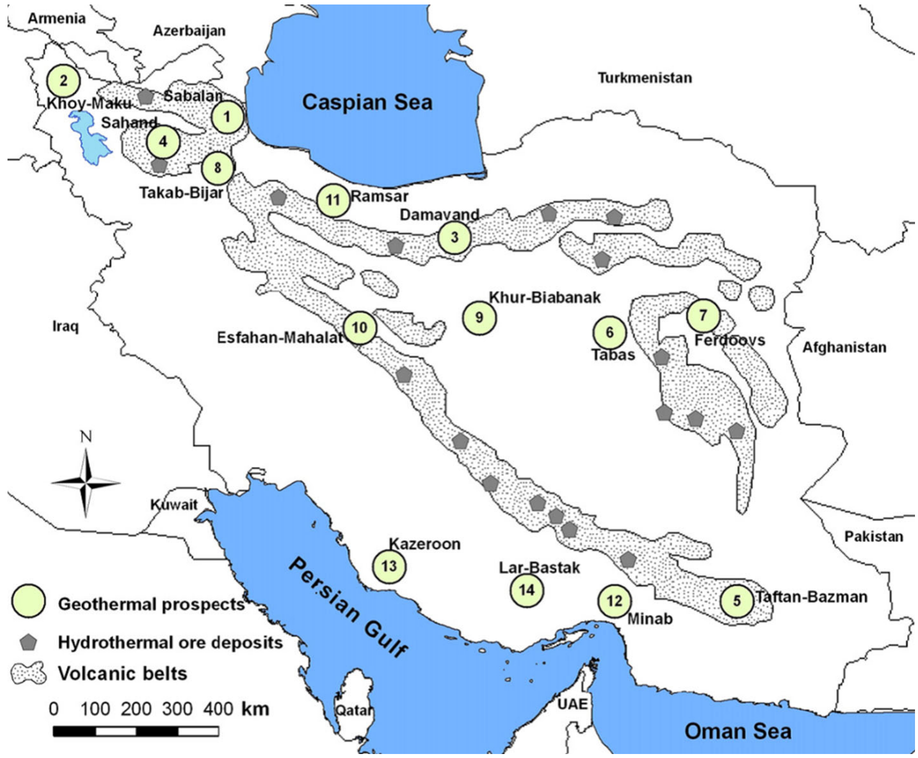

Fig. 12 Geothermal potential areas in Iran (Yousefi et al. 2010)

Table 5 Iran's non-governmental RE power plants, by 2011 (MW) (Islamic Parliament Research Center 2012)

State of plant development	Wind	Solar	Biomass	Small hydropower	Sum
In operation	28.4	–	1.6	–	30
Contracts to purchase the power	679	–	12	–	691
Initial agreement	5239	495.1	10	10.087	5754.187
feasibility study	3241.53	1085	30.7	–	4357.23
Revoked licenses	1027.5	135	126.2	30.8	1319.5

Scenario design

Methodology

In a research, Abbaszadeh et al. (2013) presented four future scenarios of Iran's oil status based on different modes of production and consumption. Like their work, the methodology applied in this study is a combination of both visualization and CIA. Two main drivers (energy consumption and RE production) are identified that can describe the future energy landscape in Iran, and four-quadrant matrix (minimal approach) helps to target the key drivers and organize the scenarios around them. This approach is suitable when the overview of all elements reveals two criteria that will allow one to determine the further development (Pillkahn 2008). Scenarios in this approach are developed in each quadrant of a grid representing the most important and uncertain scenario drivers (Schwartz 1996). The abovementioned criteria results in four alternatives from the top-down, and the elements of the future are adapted and linked according to the context. Cross-impact analysis is then adopted to help determine how relationships between these two criteria may impact resulting events and reduce uncertainty in the future. Possible dependencies, interactions, and relations can be considered within this forecasting method (Menck et al. 2014). Delphi method helps to fill the CIA matrix. It attempts to distill the opinions of the recognized experts down to a substrate that is acceptable for all. The output of the CIA matrix is afterward used as an input for scenario development using visualization. The following hereunder is a brief description of these two methods:

Cross-impact analysis

Cross-impact analysis (CIA) was developed, in 1966 by T. J Gordon and O. Helmer, initially as a game ("Future") (Glenn and Gordon 1994). Today, this instrument has a plethora of uses, alone or in combination with other methods, and it has also advanced—e.g., in the tradition of Michel Godet and the Batelle-Institute—to the status of a typical scenario technique (Mietzner and Reger 2004).

Cross-impact analysis is utilized to present the causal relationships between probabilities of different possible future events, to analyze them, and to take into account their mutual consequences (Kosow and Gabner 2008). It is used in the scenario technique above all to analyze plausibility. The main goal of CIA is to forecast events based on the principle that the occurrence of events is not independent. An individual or a group must come up with a set of interrelated events that might occur in the future. This requires users being able to modify or iterate their estimates until they feel the conclusions inferred from their estimates are consistent with their views (Bañuls et al. 2012).

Visualization

Bishop et al. (2007) classified the actual scenario techniques into eight categories. Among them, "judgmental techniques" are probably the most common one. They rely primarily on the judgment of the individual or group describing the future. Unaided judgment is the most commonly used method, but it can be supported by certain techniques such as: genius, visualization, role playing, and Coates and Jarratt.

Visualization is the use of relaxation and meditative techniques to quiet the analytical mind and allow more intuitive images of the future to surface. Individuals typically use a calming narrative, called an induction, to promote relaxation and gently direct the mind to different aspects of the future. Markley promoted such techniques, first by Harman at SRI in the 1970s and then by teaching and practicing the technique for 20 years at the University of Houston–Clear Lake (Markley 1988).

Energy scenarios for the country

To make the considered scenarios, a combination of different trends of producing REs and country's energy consumption is applied. Only three conditions (increase, decrease, and constant) are considered for each RE parameter and energy consumption of the country. Of course, certain other conditions such as fixed at first and increased later can be issued as well; however, this has been withdrawn in order to have a more simple and practical analysis. With the two discussed factors, reviewing the researches and news related to this area, and according to experts, the dominant trend was chosen for each of these conditions (shown in Table 6).

The judgment of a number of informed people is likely to be more reliable than the judgment of single individuals, since a group possesses at least as much knowledge as the least knowledgeable of its members. The Delphi method is a good empirical tool to obtain a reliable consensus of opinion from a group of experts (Buckley 1995). Therefore, in this study, the Delphi method is used to fill the cross-impact matrix. The Delphi panel participants were asked to record their thoughts about the interaction between each pair of variables. Then, their answers were corrected by an expert's opinion (Table 7). The cross-impact matrix numbers vary between −2 and +2. Positive numbers indicate the beneficial effect of trends to each other, while the closer this number is to +2, the stronger the cross-impact is indicated between trends.

The conditional probabilities of trend matrix can be obtained through the Eq. 1 (illustrated in Table 8).

$$P = 0.5 + (0.5 * \mathrm{SENS} * \mathrm{CI})/2 \quad (1)$$

where CI represents the cross-impact of trends to each other and SENS is the sensitivity coefficient which is averagely equal to 0.75.

Using Table 8, the cells with the most probability value were chosen (T1T6, T1T5, T2T4, and T3T4). Perspective

Table 6 Hypotheses, the trend of RE production, and energy consumption in Iran

Hypothesis	Code	Trend
RE production increases	T1	Increase in investment of private sector
RE production remains constant	T2	Focus on fossil fuels (current trend)
RE production decreases	T3	Improper pricing of the fuels of country
Energy consumption increases	T4	Unsuccessful implementation of subsidy reform plan
Energy consumption remains constant	T5	Implementation of rules and regulations in order to prevent the growth in energy consumption in domestic, industrial, transportation, agricultural and residential sector
Energy consumption decreases	T6	Reformation of production and consumption pattern through a successful implementation of subsidy reform plan

of the combined trends forms the structures of the scenarios. The results of these methods to attain the initial structures of scenarios are presented in Table 9. Some scenarios have been designed based on these trends which are developed as follows:

Green path

Green path scenario assumes that subsidy reform plan is successfully implemented in Iran. The former subsidized fossil fuels will increase to the actual price, leading to the balanced energy costs which forms a real contest among different energy types in order to optimize the energy basket of the country. With shift in consumption patterns, energy intensity decreases slowly, while increase in energy efficiency is expected. This energy efficiency could save 15 % carbon resources in 2025 so that the share of diesel and LPG could diminish by 50 % in rural areas. The saving in the energy consumption refers to savings in fossil fuel resources which are replaced by renewable resources. Besides, strong presence of foreign companies in RE projects as well as subsidies and preferential policies for domestic companies will result in a rapid technology switching. Solar energy will be a common source of lighting in central parts of the country, and total electricity generated by wind farms could reach about 3500 MWh by 2025. Hydrogen will be used in transportation sector in major cities, and the share of hydropower, geothermal, and biomass also grows large as the total share of renewable electricity generation reaches 10 % of total electric power generation, fulfilling the 20-year vision.

In 2012, 556.8 million tons of CO_2 equivalents, accounting for about a 98 % share of the total GHG emissions were emitted in Iran (Ministry of Power 2013). In 2025, 507 mio t CO_2 eq could be emitted which is a saving of 9 % or 50.1 mio t CO_2 equivalents. In this scenario, Iran has taken a huge step toward sustainable development and has entered the green path. The less energy consumption and more RE production mean more petroleum and gas exports which put the country into the more robust international position.

Table 7 Cross-impact matrix

	T1	T2	T3	T4	T5	T6
T1	–	−1.3	−1.5	−1.4	1.3	1.5
T2	−1.3	–	1	1.6	−0.8	−1.5
T3	−1.5	1	–	1.9	−0.6	−1.8
T4	−1.4	1.6	1.9	–	−0.7	−2
T5	1.3	−0.8	−0.6	−0.7	–	0.8
T6	1.5	−1.5	−1.8	−2	0.8	–

Table 8 Probability matrix

	T1	T2	T3	T4	T5	T6
T1	–	0.256	0.219	0.238	0.744	0.781
T2	0.256	–	0.688	0.8	0.35	0.219
T3	0.219	0.688	–	0.856	0.388	0.163
T4	0.238	0.8	0.856	–	0.369	0.125
T5	0.744	0.35	0.388	0.369	–	0.65
T6	0.781	0.219	0.163	0.125	0.65	–

Standardization

This scenario is planned through a combination of increasing REs production and the constant energy consumption. It assumes that the government has been successful in the implementation of general policies of article 44, and also the privatization process has been almost successfully implemented. Government supports the private sector in the RE area and assures the investors through ensuring the purchase of the generated electricity with an appropriate price. Small hydropower and wind energy will dominate the share of renewable resources with 50 % of total renewable electricity generation, while solar, geothermal, and biomass could see further improvements to increase the share of RE electricity to 8 % of total electricity production.

The government seeks to maintain the current energy consumption trends with actions such as: imposing fines on firms over energy efficiency failure, implementing new national green building regulations, phasing out old vehicles from the cycle, and expanding public transportation systems. With this, Iran can keep its oil exports at the

Table 9 Method results for specification of scenarios framework

Scenarios	State of RE production factor	State of energy consumption factor	Combination of trends with high occurrence probability
Green path	High	Low	T1T6
Standardization	High	Constant	T1T5
Fossil energy	Constant	High	T2T4
Non-targeted subsidy	Low	High	T3T4

current level with the opportunity to finish developing its giant South Pars gas field within 3 years and subsequently, offering an opportunity to export more natural gas to its neighbors.

CO_2 emission is expected to remain unchanged under the standardization scenario as fuel combustion will stay the most major emitters with 175 mio t CO_2 equivalents. GHG emissions in transport sector could slightly increase, while this share for heating would abate due to more RE use in urban and rural areas.

Fossil energy

Fossil energy scenario envisions that Iran will continue its concentration on using fossil fuels. The higher rates of oil production accounts for the energy intensity increase as subsidy reform plan implementation is faced difficulties. With no change in consumption patterns, energy demand rises in the industry and commercial sectors. Hence, despite the maximum production policy, oil exports are expected to decrease to less than one million barrels per day in 2025. Since the current policies continue to work, RE infrastructure will not see much of an improvement under the scenario. Unstable legislation, lack of financial support, limited foreign investments, and no major change in privatization process result in the stagnation of RE development. High-cost solar and wind power with no advance in geothermal, biofuels, and biomass simply reflects the government's lack of enthusiasm for renewables. Under such circumstances, unfinished RE projects face funding problems, and low efficient technology increases the gap with leading countries.

During 2007–2012, the average growth rate of CO_2 emissions from fossil fuels in Iran had been 2.5 % per year. This upward trend is projected to continue to reach about 725 mio t CO_2 equivalents in 2025. Industry and commercial sectors in this scenario will see the most increase, while heating in urban household sector would remain almost constant.

Non-targeted subsidy

The most pessimistic condition to be imagined for the country is high energy consumption and low RE generation. IEA has lately announced Iran as the world's number one energy subsidy payer (Badamfirooz and Mahesha 2013). Mainly, subsidies are paid for oil, natural gas, and electricity products in Iran. Almost 72 % of the overall subsidy payments go to oil products according to 2006 figures. In numbers, it reached 469 billion *rials* (Iranian currency) as of 2007 (Tiglay 2014). Badamfirooz and Mahesha (2013) conclude that the Iranian subsidies aiming at helping the industrial sector have not succeeded in raising industrial output levels. It has rather swollen out energy demand and carbon emissions.

Non-targeted subsidy scenario denotes that Iran has failed in implementation of the subsidy reform plan. The already strong dependence on fossil fuels faces more difficulties where oil exportation gradually stops by 2025. Energy demand rises in all sectors as the increase will be particularly steep in the fuel combustion and commercial sectors. Besides, there will be no change in energy efficiency as the share of diesel and LPG consumption in rural areas could rise up to 20 %. As for renewable resources, little tendency exists for using REs in society. In the absence of foreign investments, renewable power generation is unprofitable for domestic companies, mainly because of significant cost differences between REs and conventional energy sources. The low cost of CNG could out compete new and fragile renewable industries. It may prove to be a "termination" fuel rather than a "transition" fuel. The rate of CO_2 emissions in this scenario is estimated to increase rapidly from 2.5 % in 2007–2012 to 8 % in 2025, while the share of CO_2 emissions from natural gas is projected to rise from 53 % in 2012 to about 74 % in 2025.

Discussion and model analysis

Before analyzing the long-term prediction, a summary of the presented scenarios in the previous section is illustrated in Table 10. These scenarios are obtained through investigating the country's current status with combining the predictions of RE production and energy consumption.

By combination of Delphi and expert opinion methods, after identifying the scenarios' requirements and framework, prediction of energy consumption and RE production for each scenario is obtained (shown in Figs. 13, 14). The participants of Delphi panel were asked about energy consumption and RE production rates according to assumptions of each scenario. Their answers were corrected by expert opinion, and quantitative predictions for each scenario were obtained. General assumptions for each scenario are summarized in Table 11.

Energy use is expected to increase by 83 % until 2025 if no counter measures are taken. Based on this research and beyond according to Research Center of Parliament, consequences will be a high reliance on fossil fuels: a decrease in energy security, continuation of low energy efficiency, decrease in oil exports, higher levels of air pollution and consequences on human health such as lung cancer and chronic respiratory air diseases, a higher contribution to global climate change and associated impacts such as extreme weather events like droughts, sand storms. This will lead to high externalities resulting in additional costs

Table 10 Summary of energy scenarios

Scenarios	RE production	Energy consumption	Characteristics
Green path	↑	↓	Actual fossil fuel price leads to the balanced energy prices and optimized energy basket It encourages the active participation of private sector and foreign investors in RE projects Successful renewable energy transitions and entering the green path
Standardization	↑	Constant	The privatization process are almost successfully implemented by the government Government looks into involving the private sector through supportive actions The target is to maintain the current energy consumption trends
Fossil energy	Constant	↑	Focus on fossil fuels will be continued Difficulties in reform plan implementation leads to the increase in energy intensity Stagnation of RE development, RE infrastructure will not see much of an improvement
Non-targeted subsidy	↓	↑	Low fossil fuel price leads to significant cost differences between REs and fossil fuels Heavy dependence on fossil fuels, it is utilized merely for domestic consumptions Little tendency to use REs in society, renewable power generation will be unprofitable for domestic companies

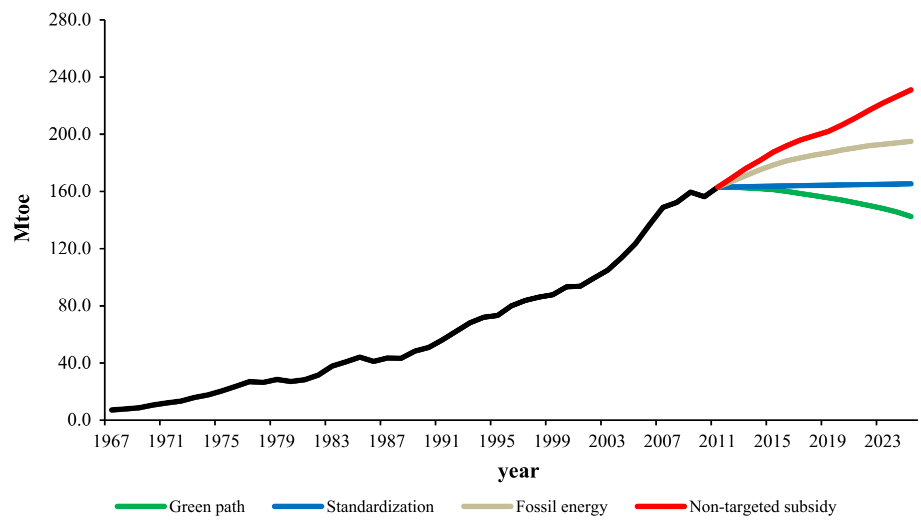

Fig. 13 Energy consumption in Iran under the developed scenarios

for fossil fuels which have so far not been assessed. Difficulties in subsidy reform plan play the main role in rapid rise of energy demand and GHG emissions in the transport sector, because of rising affluence levels as well as high growth rate of car ownership. Besides environmental and health issues, the consequences of an increase in the transport demand will be higher traffic volumes, longer peak-hours, a higher frequency and duration of traffic jams, and an insufficient transport infrastructure (Urban 2009). In general, the government will have a crucial challenge to modify fossil fuel consumption increase in the upcoming years. The consequence of failure will not just be on energy sector, but would affect the whole economy and will most likely send the country into recession.

For RE deployment, a substantial amount of capacity addition is needed by 2025 for both green path and standardization scenarios to meet the 20-year vision. A comprehensive energy sector reform plan entailing clear long-term objectives with an extensive communications strategy is the main essential driving force toward RE transition. Arranging finance, strong participation of the private sector, technical assistance, and stable legislation could also encourage domestic companies in expanding distributed generation from wind, solar, geothermal and, etc. In this

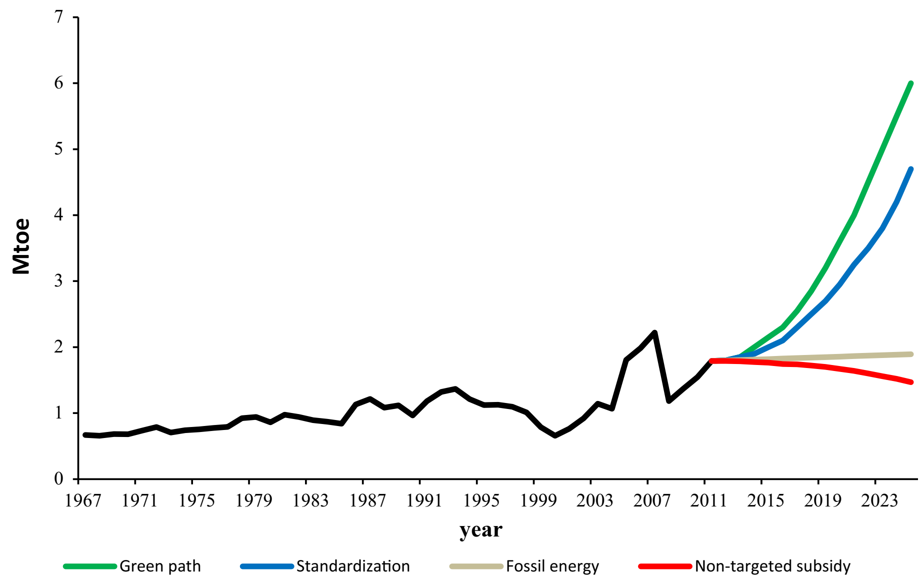

Fig. 14 Renewable energy production in Iran under the designed scenarios

Table 11 General assumptions for energy scenarios

Scenarios	Energy efficiency	Renewable electricity contribution rate (%)	Subsidy reform plan outcome	CO_2 emissions growth rate (%)	Share of diesel and LPG consumption in rural areas	Oil and gas exports	Foreign investments in RE projects	Technology switching
Green Path	High increase	10	Successful	−9	Reduce by 50 %	Increase	Strong	Rapidly
Standardization	Slight increase	7.8	Successful	0	Reduce by 15 %	No change	Strong	Slowly
Fossil energy	No change	3	Partially successful	+2.5	No change	Decrease	Limited	✖
Non-targeted subsidy	No change	0.25	Unsuccessful	+8	Increase by 20 %	No export	No participation	✖

direction, including the externalities of fossil fuels like health, climate, and environment into their prices could cut the cost difference between REs and fossil fuels. In green path and standardization scenarios, the consumption of gas oil, fuel oil, and blast furnace gas would diminish, whereas REs could reduce the share of fuel combustion sector for producing electricity. The technological improvement in the green path and standardization scenarios will results in lower energy intensities and higher efficiencies. The potential for using REs for heating in urban residential sector could increase, while REs are likely to be highly welcomed in rural areas, because of abundant renewable resources and lack of access to fuel markets.

Because of sharp increase in energy consumption in industrial, commercial, and transport sectors, GHG emissions in major cities are expected to grow rapidly in the fossil energy and non-targeted subsidy scenarios. This upward trend would be slowed down by introducing hydrogen for public transport. The more shares of other lower-emission fuels such as natural gas for power plants and also CNG in rural areas are projected for green path scenario. Besides, realistic REs implementation combined with a partially successful demand restriction could indeed mitigate the country's environmental burdening.

Conclusion

This study developed four scenarios on Iran's energy sector, with a stress on the underlying but key RE production. An overlook of the two main criteria as the main drivers for the country's energy sector (energy consumption and RE production) has been provided. The challenges and characteristics of these two parameters were discussed, leading to the four general scenarios along with a discussion on the government plan for RE production. And subsequently, a quantitative prediction of both criteria for each scenario has been represented. Based on the discussions and finding of this study, the two scenarios of standardization and fossil energy are more likely to occur in the 2025 vision in Iran. Standardization scenario emphasizes on the government's role for keep the energy consumption almost constant, while fossil energy scenario suggests that the lack of government's ability to implement national planned programs will result in a huge increase in energy consumption.

The developed scenarios in an analyzed and classified frame tried to address an appropriate direction for the country to move toward sustainable development. The future energy scenarios were discussed in this study in order to codify a general policy to achieve sustainable energy in the country. Therefore, since the suggested plan proceeds to analyze the future energy scenarios generally, visualization of the probable, acceptable, and preferential futures in energy arena would be possible. Should this area be visualized, the policy needed by managers to achieve "what they want," would be simpler and more realistic. Developed scenarios and predictions through this research can be applied as a potential tool for researchers on energy planning to determine the energy strategies in order to direct politicians and managers in this arena, so that they can consider a comprehensive general plan and make the right decision through having future images of the country's energy situation.

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