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A Sustainable Transition to Renewable Energy Resources in Oil Producing Countries: A Case Study of Iran

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A B S T R A C T

Iran owns various resources for energy production, including natural resources and land. Although the country holds one of the biggest fossil fuel reserves, the country's development plan and international commitments requires the reduction of GHGs and the implementation of clean energy generation. Despite the various plans and institutional support, the country's dependency and trajectories for investment on oil industry, cheap resources of fossil fuels, the lack of infrastructures and technology are the main barriers for this transition. Governmental support, CO2 pricing and foreign investment (associated with technology imports), are the proposed methods for overcoming the barriers and to facilitate the transition process to renewable energy resources

1. Introduction

Reduction of greenhouse gases (GHG) emissions is a target for every country as an effective factor for reducing the negative effects of climate change and global warming. Energy generation and consumption is responsible for two third of these emissions. Low carbon energy production and energy efficiency are the two main solutions for reduction of GHG. United Nation's Framework Convention on Climate Change (UNFCCC) actions in the Paris agreement have become the cornerstone of this movement. Based on the commitments in this conference, members should increase their share of renewable energy from 15% in 2015 to 65% in 2050. The transition to renewable resources, associated with energy innovation, new market design, new financing and business models, new policies and technology transfer, might be a path way for cutting emissions. Long term policies such as: efficient renewable energy subsidies, carbon pricing and increasing the investment in the sector are also required for the transition process. Iran, one of the biggest owners of fossil fuels, committed to reduce its emissions up to 12% by 2030, but it is not the only motive for the transition of the energy sector. In Iran's sixth 5-year National Development Plan (NDP), as a part a 30-year plan, the growth in the share of renewable resources is targeted to be up to 5000MW. Additionally, the decreasing cost trend of renewable resources, the converging fossil fuels costs and the attractiveness of the foreign investment in Iran's renewable energy sector, constitute further motivations for this transition [36]. Identifying Iran's energy sector structure, its potential and its role players on one side, and its methods and institutions on the other, would be helpful to develop a pattern and respective policies for transition of Iran to renewable energy.

In this research, we first try to summarize the main theories and approaches of a sustainable transition to renewable resources in order to highlight its main drivers and barriers. Socio-technical approaches, such as socio-technical transition and energy development blocks, help us identify the structure of Iran's electricity power sector and the possible scenarios for its transition to renewable resources. For this regard we apply the mentioned theories to our data set in order to identify the characteristics and possibilities of Iran's electricity sector for a sustainable transition. Finally, based on the conducted analysis, some policies and methods will be proposed.

The structure and the share of primary energy resources constitute effective information for clarifying the country's development blocks and socio-technical elements. Reserves, production levels, costs and the share of production of different energy resources will be analyzed to further this discussion. Economic incentives, such as cost and institutional drivers and environmental concerns will be studied in order to find the possible methods or policies for transition.

What we discuss mainly in this study is changing the primary carriers rather than the end service [1]. Since the necessary technology shift is difficult, pinpointing the barriers for development of renewable resources, such as low price of fossil fuels, technology limitations, path dependency and investment deficiency in the energy sector will be discussed [1]. Finally, some applicable methods regarding to the drivers and barriers of transition of the country's energy sector to renewable resources will be proposed.

Despite of domestic (high potentials for power generation and determined share of renewable energy resources in the national development plan) and international motives (UNFCCC commitments and decreasing renewable cost trend) the share of renewable resources in electricity generation is very small. Resources, such as hydropower, solar and wind power can play an effective role in increasing the share of renewable energy in the country. Although there are considerable natural and institutional potentials for the development and transition to renewable resources, the low cost of fossil fuels and lack of infrastructures for the renewable energy resources, as a high-tech industry, are mentioned as the main obstacles for the growth of the renewable energy industry. On the other hand, recent domestic and foreign investments in renewable energy projects, particularly solar and wind energy power units show the tendency for investment in this sector. Investment of 51,725,000 EUR and the construction of 5 solar PV power units with a generation capacity of 44 MW in last 12 months show the increasing attractiveness of this industry. The country previously used to generate less than 1 MW of this kind and the recent investment in renewable energy sector continues. The above discussions about drivers, potentials for transition and recent investments in Iran's electricity energy sector, raise the following research questions:

- Based on Iran's electricity power generation, consumption and potentials, is it feasible for the country to transit to renewable resources?
- What are the main barriers and drivers for the transition of Iran energy sector to renewable resources?
- Which methods/patterns are helpful to overcome these barriers? Is it applicable to other oil producers with cheap fossil fuel resources?

2. Materials and Methods

2.1 Theoretical Context

The theoretical context of this thesis, like any case study, is a framework for categorizing and analyzing the case based on the developed theories and conducted researches. Regarding the research questions and context, we use a theoretical perspective to analyze Iran's energy sector's barriers and drivers of transition to renewable energy resources, as well as the respective methods and patterns for this transition

Sustainable energy approach is helpful to identify drivers, barriers and potentials of energy sector for the transition process. Energy development blocks theory defines the share of different energy carriers and their respective innovation by analyzing supply and demand, energy efficiency and price trends as a result of market mechanisms. Since the transition process includes different technical and social aspects, the socio-technical transition theories are helpful to identify different barriers and drivers of energy transition in Iran. After analyzing the energy sector policy oriented approaches, such as carbon pricing or energy subsidy, a pathway can be proposed for the energy sector transition.

2.2 Sustainable Energy and Drivers of transition

The MacKay's perspective Sustainable Energy (2009) reviews the motivation and the feasibility of transitioning to renewable energy resources. Although countries like Iran own abundant and cheap fossil fuel resources, even these big reserves are limited and will be depleted in the coming years. Thus, the country should plan for the substitution of these resources and use them for other purposes with added value. Investment of the income earned by selling these added value products, or using them as input in a production process, would increase the GDP and boost up the economic growth. Another motivation is energy security. Although fossil fuels might seem a secure option in the short term, as they will vanish in the near future, they are not a secure option in the long run. Also, the proved adverse effect of fossil fuel consumption, which tends to environmental disasters and climate change, needs to be taken into consideration [2].

In order to analyze sustainable energy theory, we review the different potential and reserves of various available energy resources in Iran to address the energy security motive .This aspect of transition is already considered in Iran's National Development Plan which we will discuss later. Price trend comparison of fossil fuel and renewable energy resources will show to what extent the current cheap fuels are reliable and long lasting. Finally, the country's concern about GHG emissions and its commitment with the international community to cut them also shows to what extent the third major motivation and environmental issues matter for Iran.

2.3 Energy Transition Theories

2.3.1 Socio-Technical Transition of the energy Sector

Socio-technical transition is a concept defined by Geels [12] as one based on three major fields of evolutionary economics, sociology of technology and innovation studies. In fact, this theory addresses what Schumpeter discusses as non-economic forces in his theory of economic development. In the modern age, and after the industrial revolution, different technological innovations were created and diffused at a high pace. Technological transition is the process that explains how the innovation takes place and how it integrates in the society by studying social changes. The changes in infrastructures, regulations, user practices, industrial networks (production, supply, and distribution), culture and symbolic meaning of technology could be mentioned as major social factors in this process. A technological transition contains key alterations in the socio-technical structure, including substitution of technology, which starts from one element and transforms to others [12]. Since the socio-technical systems and transition are complicated to understand, researchers created a model called Multi Level Perspective (MLP).

MLP is a socio-economic approach which recently has been applied to different economic and social subjects. According to this theory, a sector such as energy could be considered as a socio-technical system. These systems consist of different elements including; actors (such as individuals or organizations), institutions (standards, regulations and norms), material and knowledge. The services provided to society are the result of interaction between the mentioned elements, which shows to what extent they are dependent on each other and interrelated together [19].

Institutional or fundamental change in these socio-technical systems can lead to socio-technical transition. The changes could be economic, political, institutional, technological, etc. These changes could result in new, complementary or in the substitution of services, products, organizations and business models. Socio-technical transition is not comparable with the technological transition as it is also accompanied with institutional structures, practice changes and non-technological innovations. If a socio-technical regime shift takes place in conformity between production and consumption, it would be a sustainable transition [19]. Multi-level perspective is considered as an approach to analyze technology transition through interaction of elements at three levels, including: niche, landscape and regime.

The technological niche is a protected market, space or application so called "safe heaven" for the development of incremental innovation away from the pressure of the dominant regime [19]. Niche is related to micro-level innovations and protects them from the pressure of the free market which regularly exists at regime level. Both producers and consumers in niche level create a protection for new technologies in two main parts of market and technological niches [12].

The socio-technical regime is the product of the history and sociology of technology in combination with the concepts of evolutionary economics. In fact, this regime creates a direction for incremental socio-technical change in the development path already established [19]. The regime level, which is concentrated on meso-level innovation, is a network of communities and social groups which are interconnected by a set of rules. Unlike the change in niche level, changes in regime level are incremental and slow. A technological regime also creates the trajectories and performs as a rule-set [12].

Socio-technical Landscapes are the facilitators and opportunity makers for niche to step forward and play a role in fundamental shift or changes in regimes [19]. Landscape level is connected to macro level innovation and is exogenous to regime and includes macro level dimensions of environmental issues, social trends and cultural values. It also consists of a set of rooted structural tendencies and modifications [12].

The MPL mechanism in summary operates as follows: a micro innovation at the niche level exerts a force by implementing price or performance improvement, learning processes and receiving support from powerful communities. This movement transforms the landscape level and puts pressure on the regime. The pressure on the regime destabilizes this level and creates an opportunity for niche innovation to move to the next level [13]. Technological transitions have common characteristics, including: transitions are co-evolutionary and multi-dimensional; they include multi-actors; it happens at multiple levels; and it is a long-time process which is radical and non-linear [13].

2.3.2 Path Dependency and Development Blocks

Development Block is a Schumpeterian rooted concept which was first developed by Erik Dahmén. He identified a group of closely interrelated and inter-reliant elements in industrial development while conducting a study about Sweden Industrial economy. This process shows the indicators of price, cost or emerging markets made by entrepreneurial events. According to this concept, transformation is located between two severe conditions resulting from new methods of production or providing services, market, and sources of energy. A development block might be completed by a group of entrepreneurs and through uncoordinated events. Diffusion of technology and transition might face several issues, such as narrow market and the excess of capacity as a result of failing to find new markets. This could be solved by implementing marketing and sales promotion. Subsidiaries and expanding interests are two other solutions for this problem. Development blocks are wide socio-economic networks made of cumulative components [7].

Although Dahmén defined the concept of development blocks for the technological and industrial sector, Kander [1] developed this concept for the energy sector. The first step for identifying energy development blocks is pinpointing the contribution of energy to the economy. The role of energy in economic growth, drivers of energy transition and the role of energy in the economic efficiency are the main contributions of energy to the economy and development blocks [1].

The price, cost, environmental effects, technological progress and share of energy in the economy are some variables which are determinant in economic growth. Price of energy carrier is a key variable in the economy since it affects production, economic growth and, ultimately, development. For instance, the cheapness of energy is not necessarily an unimportant sign, as it might show some qualitative progress in infrastructures that result in increased production and cost reduction. On the other hand, price of energy, as the core of development block, affects fundamental parts of economy, such as infrastructures, design and transportation. In a general perspective, development blocks formulate the economy, but they themselves are dependent on energy carriers and these carriers are accompanied with particular technologies. This concept is known as path dependency and shows why the cost of energy transition is high since it affects the whole economy [1].

Although the energy sector transition is expensive for the economy, the drivers for transition in this sector always exist. Like the industrial sector, energy development blocks follow the same pattern of complementarity between energy carriers and associated technology. Since development blocks consist of different elements other than technology, such as energy sources, institutions and infrastructures, transition takes time. In fact, development blocks are made of discontinuous phases resulting from the lag between innovations and their wide spread use, which shows the necessity of transformation in all the components of the energy sector [1].

Another contribution of energy to the economy is the energy efficiency. In simple terms, energy efficiency is a measurement for showing the required unit of energy for one unit of production. Energy efficiency in development blocks could be discussed in two major categories of energy saving and energy expansion. Capital deepening, expansion of the service sector and modification of the economic structure in modern economies are signs of an increase in energy efficiency [1].

Core innovations, which are the macro innovation of a development block, could be considered to be a General Purpose Technology (GPT) in case of a widespread application. Market suction and market widening, are important regarding to the complementary innovation and diffusion of new technology. While market suction oversees the relation between innovation and its own requirements as complementary drivers for diffusion, market widening considers the process as a result of lower prices of energy carriers, particularly in relation to the prices of transport and communication [1].

Based on the mentioned contributions of energy to the economy, three modern development blocks, including Oil- Internal Combustion Engine (ICE), Electricity and ICT Development Blocks could be mentioned [1]. The Oil- ICE development block formed around the internal combustion engine has the oil as the carrier and is mainly used by the transportation sector [1]. While pipelines and tankers performed as market suction mechanism of this block by reducing the oil prices, ICE was the core of the market widening mechanism [1].

The electricity development block holds the electrical motor, generators and transformers as the core innovations inside. The flexibility of electricity as a secondary energy in generation and consumption were the main advantages of this block [1]. The balance between generation and consumption in this energy carrier is very crucial due to the characteristics of electricity. As a result, system expansion played an important role in the market widening of this block. The need for higher energy efficiency, flexibility of electricity power, and the oil crisis in 1970s were some of the drivers of transition to electricity block. However, electricity is difficult and expensive to store, and it needs a big financial power to run [1].

The ICT development block is the result of communication technology and microelectronic invention. ICT, as the most energy saving development block, benefited from expansion of higher education and the requirement for stored and accessible codified data inside machines [1]. Considerable increase in efficiency, a decreasing trend in computers prices and dematerialization are the characteristics of this block [1]. While large computers acted as the market suction mechanism of ICT-Block, Internet, PC and cell phones are the markets widening facilitators of this block. Information and communication society, which was created by the ICT-Block, is more focused on energy saving [1].

As mentioned earlier the costs of energy carriers, either social or private, are really vital to development blocks and transition. While private costs are usually reflected in the energy carriers' price, the social costs such as environmental or health costs are not captured [1].

Development block and path dependency are two important concepts in energy transition theories. The transition or change in the energy sector is directly connected with economic growth and the development of a country. Although the transition to fossil fuels was one of the most important in the 20th century, it was not the only. The new transition wave is more concentrated on the electricity production, which has no strong substitution despite changes in the level and forms of electricity generation. There are always a complementary relationship between new technologies and energy carriers, but the transition of the energy sector is a regime change that requires a shift in organizations and infrastructure developments in addition to a shift in the technology. In fact, it is not only a matter of process change, but also the infrastructures [1].

Applying the development blocks concept to energy sector is helpful to identify the role of different blocks in the transition and diffusion of new technologies, as well as the mechanisms of market suction and widening [1]. This theoretical framework could be used to pinpoint the path dependency, trajectory and the possible effects of choices for Iran's energy sector [1]. The concept of path dependency tries to illustrate that decisions made in the past have an influence on the path taken in the future [1].

2.3.3 Comparison between Socio-Technical Transition and Development Blocks

Path dependency in the energy sector could be either the result of a relative price of energy carriers such as cheap fossil fuels, or a result of the plans and infrastructures that play a critical role in the economic growth. In fact the path dependency could be studied in order to find the patterns of development and answer the question posited: will the economies find an efficient and sustainable pattern for their energy sector or follow the conventional trajectories? Path dependency and cumulativeness are two major issues for socio-technical regimes. In modern economic development, patterns and particularly the energy sector quality is as important as quantity. It means that the convergence in environmental issues and energy intensity in relation to growth is as important as the convergence of growth, structure and productivity [6].

The performance and characteristics of a socio-technical system have a close similarity to development blocks as they both consider the transition in the energy sector with technology innovation as their core, and both are associated with other social, institutional and infrastructure elements. The sustainability challenges are coupled with strong path-dependencies and lock-ins we observe in the existing sectors [19]. As Macro-innovations diffuse, they change the society and economy and they tend to form new development blocks. These macro-innovations necessarily need niche market, micro and meso innovation and complementary innovation for diffusion and wider implementation. In addition to technology innovation, capital investment, new infrastructures and institutional activities are required for a wider socio-technical transition. Complementary institution, infrastructure and products are essential for the diffusion of new technology [1].

2.4 Co2 Pricing methods

We mentioned the climate change and particularly the UNFCCC Paris agreement in 2015 as a motivation for a transition to renewable energy for Iran's economy. One major contributor to the recent climate change is the burning of fossil fuels their resulting GHG emissions, including carbon dioxide. These negative external effects that are caused by these emissions are regularly not included in these carrier's prices. The method for calculating these costs in energy price is so called "carbon pricing". In fact it is the extra cost charged for the emission of CO2 to the atmosphere. The carbon pricing methods try to reflect benefits of clean resources and costs of fossil fuels in the energy market [22].

Sustainable development includes three main components: the economy, environment and society, and carbon pricing can play an important role in this process. The latter is a handy tool for the Intergovernmental Panel on Climate Change's agreements targeted to control global warming. Flexible economic transition and green economic growth are some of the aims of this method, which motivates all the consumers to reduce their emissions by shifting to cleaner energy carriers, as well as to the development of innovations to increase efficiency [22].

The two major methods of carbon pricing are carbon tax and Emission Trading System (ETS). Carbon taxing is a tax which is directly charged on GHG emissions at a specific rate. ETS is a trading system of emissions with supply and demand mechanisms for determining the GHG emission price. In this system the trade between different economies is based on the level of emissions [22].

Carbon pricing is experiencing an increasing trend of diffusion as 40 countries, averaging 12 percent of the global emissions, are currently using this system. It is a 7 billion tons carbon dioxide that is worth around USD 50 billion [12]. Private companies are also role players of carbon pricing method as they have their internal system called "shadow carbon price". This is a method that 453 global companies implemented to identify their corporate risks regarding to the climate change. This method helps companies prioritize investments on both renewable energy and energy efficiency [12].

The movement for global carbon pricing started as a result of the Kyoto protocol (1997) on climate change, but failed as it did not included major emitters. UNFCCC Paris agreement on climate change grounded the intended nationally determined contributions (INDCs) as well as the proposals of 162 countries for carbon pricing in 2016.This movement targeted to expand carbon pricing 25 percent by 2020 and by 50 percent by 2030, thus deepening carbon pricing and enhancing international cooperation. The main difference of the recent agreement from Kyoto agreement is that it covers the majority of emitters (61% global GHG emissions), including six main world leaders. Although there is doubt about the future of the global carbon pricing trend, particularly in relation to the US, other main leaders like China are developing their plans for national ETS [12].

There is an ongoing debate about subsidizing renewable energy called the green paradox. In general, taxation of fossil fuels and subsidizing the renewable energy sector policies target the demand side and not supply side with an announced time plan. The mentioned policies will make fossil fuels suppliers extract more and invest the income in the capital market. These higher volumes of extractions contradict the environmental policies that were set to provide a greener environment [18].

3. Iran Energy Sector

In order to analyze Iran's energy sector we first need to review the share of different resources in energy and particularly electricity generation and consumption. Next, we need to review share and potentials of energy resources in the country, as well their capacity trend in the recent years. Finally, we need to analyze Iran's energy sector's cost trends in the last years.. In this regard we have categorized resources as fossil fuels and renewable energy resources.

3.1 Iran Energy Reserves, generation and consumption

Iran is one of the biggest owners of fossil fuels in the whole world .These big reserves of fossil fuels are exceptional as the country is the largest owner of oil and gas resources worldwide. Despite their advantages, such as short term energy security, they might prove be insecure and instable in the long run. As the country relies on these abundant and usually cheap resources, any variation in the production, reserve or price of fossil fuels will affect the security of energy supply. While a more diversified primary energy structure could ensure this sector in the case of crisis, a dependent energy structure could have an adverse effect on the whole economy and in the economic growth as a result.

Another issue for an owner of big reserves like Iran is the economy's dependence on the fossil fuels' export income. Reliance of economies on their exports of natural resources can cause a problem named "Dutch Disease". This is a theory originated in a historical event in the Netherlands connected to the natural gas fields discovered in Groningen region. This concept developed in the 1970's and relies on the connection of the increase in the development of one economic sector (a natural resource like oil) and its connection to other sectors (like industry). The mechanism makes income flow predominantly to the growing sector while making other sectors less competitive [8]. As long as a big share of the country's exports and revenues are dependent on one natural resource, any fluctuation in the price of the product can affect the economy. In an economy like Iran, which 90% of exports and 60% of revenues are based on oil, even higher revenue of the country could not compensate the budget deficit because of high subsidies in the energy sector [9]. Transition to renewable resources makes this sector more sustainable while reducing the dependability on fossil fuels and overcoming the Dutch Disease.

Figure 1 indicates the share of different energy resources in primary energy consumption in Iran in 2013. As it is showed the majority of primary energy is supplied by fossil fuels. Although 60% of the energy share is provided by gas, which has the least volume of carbon emissions among fossil fuels, the small share of renewable resources is still notable. Fossil fuel consumption for energy generation is the major producer of GHG for which, energy efficiency and transition to renewable resources are two major suggested solutions. Crude oil, natural gas and coal are the main resources of fossil fuels in the country [20]. Referring to the development blocks theory the share of fossil fuels shows the dominance of ICE-Oil development block. A part of these fossil fuels are used for electricity generation. This fact shows the importance of the Electricity block but a small share of renewable resources might be the result of a minor ICT block.

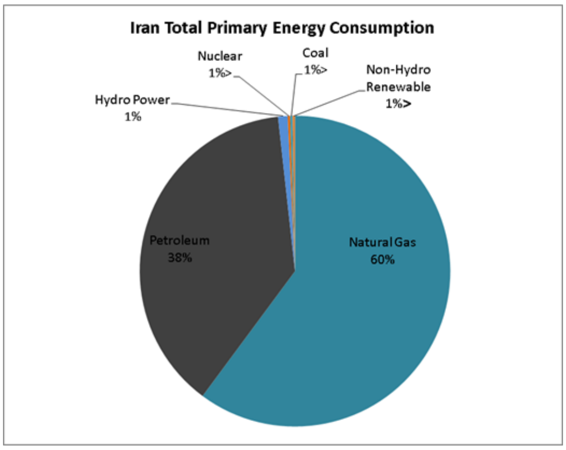

Figure 1- Iran total primary energy consumption (EIA, 2013)

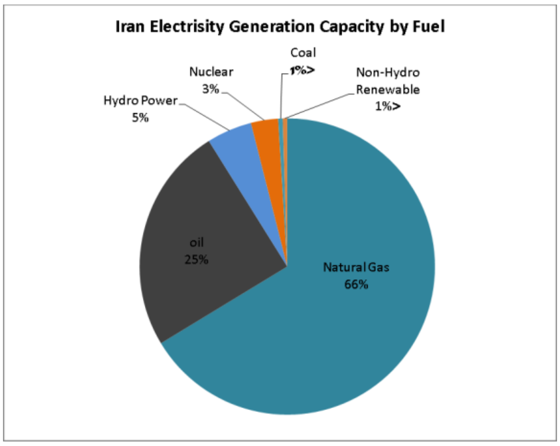

Figure 2- Iran electricity generation capacity by fuel (EIA, 2013)

The dominance of fossil fuels is also considerable in electricity generation. As it is illustrated, around 93% of the country's electricity is generated by fossil fuels. This composition of resources shows that whole energy sector electricity generation is not diversified based on the carriers in accordance to the energy sector. Although the country owns big reserves of oil and gas, their big share in energy generation can cause insecurity and instability in some cases. Recently the increase in demand for energy, as a result of the increase in population and production, has raised the initiative to search for other potential energy resources. The electricity power sector is experiencing a 6.6% average growth in the last decades, and it provides energy service to 27.2 million consumers, of which 81.8% are residential [24].

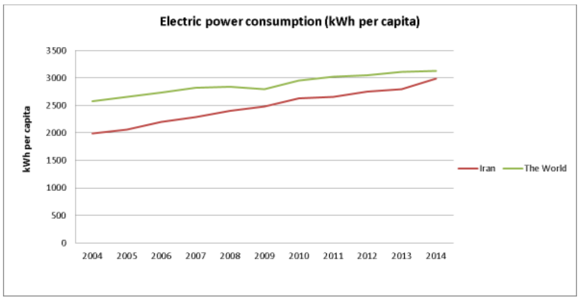

Figure 3- Electric power comparison - Iran and the world average [38]

As a result of this increase in energy consumption, in an energy sector which relies on a big share of fossil fuels, the demand and extraction of these types of energy carriers will drastically increase. The lower volume of energy consumption per capita in Iran, in comparison to the world's average, could be considered as one of a developing economy and lacking in technology and efficiency. It also means that still the ICT development block is not a dominant block in the country's development blocks and that the share of services compared to products is much lower. Otherwise the trend of energy consumption would not be higher than average with an increasing trend.

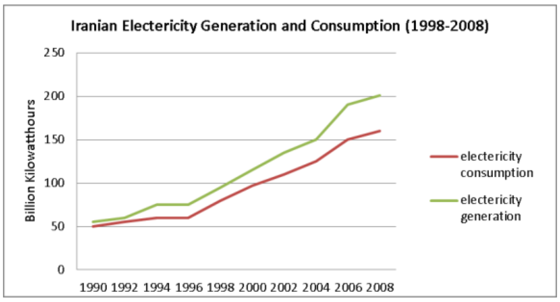

Figure 4- Iran electricity generation and consumption (EIA, 2009)

Figure 4 also shows the electricity consumption and generation has experienced a high increase during recent years as consumption almost tripled in a decade from 1996-2006. This could both show the development of the electricity block and a lack of efficiency as the major sign of ICT block

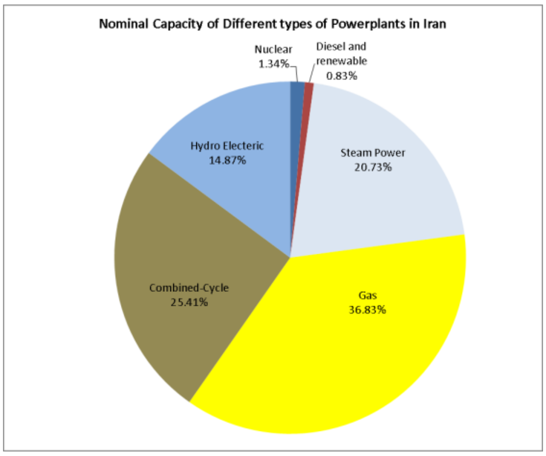

Figure 5- Iran electricity generation capacity by fuel [30]

The transition relates more to the primary energy carrier as we cannot replace electricity. Hence, the country's power unit's composition and their capacity are relevant. In 2016 Iran added about 2324 MW (a 3.1% increase) to its electricity capacity and the total electricity capacity has reached to 76427 MW. However, the share of clean energies in the mentioned increase was only 94 MW, including 19 MW renewable and 75 MW hydroelectric resources.

Table 1 illustrates that even if we count nuclear and hydro power as renewable energy resources, they present a low portion of electricity generation. Reviewing the mentioned nominal capacity also shows the highest increase in generation capacity belongs to the gas and combined cycle power plants, and that renewable power units did not experience a considerable increase.

Table 1- Iran electricity generation summary [30]

	Type	Nominal capacity 2016	Total Cap 2016	Nominal capacity 2011
Thermal	Steam	15830	63863	15821
	Gas	28124		24342
	Combined cycle	19470		14780
	Diesel	439		408
Renewable	Hydro	11350	12563	8745
	Nuclear and Renewable	1213		1116

Table 2- Iran electricity generation changes 2014-2016 [30]

	Type	change 2016 to 2015	Average change 2016 to 2015	change 2012 to 2011
Thermal	Steam	0.00	3.62	0.05
	Gas	4.67		6.82
	Combined cycle	5.28		6.52
	Diesel	0.00		7.60
Renewable	Hydro	0.64	0.74	11.44
	Nuclear and Renewable	1.68		5.82

The growth rate of power units show a small number of renewable resources in comparison to thermal power plant, particularly gas and combined cycle in recent years. The only considerable growth rate in the renewable sector belongs to hydro power. Although hydro power is one of the cleanest and more efficient types of renewable resources, it is mostly dependent on dam construction and the water resources management sector, and therefore cannot be counted as an independent power unit

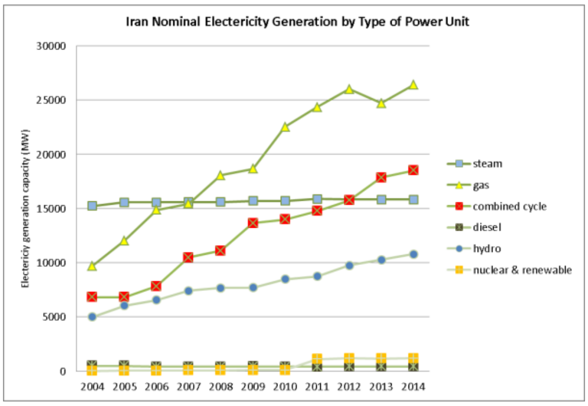

Figure 6- Iran electricity generation by type of power plant [31]

Figure 6 clearly shows the gap between renewable and thermal power plant capacity trends. It is obvious that the renewable resources graph located at the bottom of the figure is lagging behind. The thermal resources show an upward trend, particularly in the gas and combined cycle power plants as a result of the abundant and cheap gas reserves in the country.

One important aspect and characteristic of development is sustainability which should be considered for every single element of this process. Energy can play an important role in a sustainable economic development by supplying secure, efficient and environment friendly supplies for economic growth. Compatibility of energy generation and consumption is also another sign of energy sustainability Variety of energy resources and energy supply diversity is also another important element for sustainability and getting away from monopoly [5]. In order to have a more comprehensive study of the energy sector and to further the analysis of sustainability transition, we must review the capacity and potential of Iran's major energy carriers for electricity generation in two major categories, fossil fuels and renewable resources.

3.1.1 Fossil Fuels in Iran

3.1.1.1 Oil

Iran ranked as the 4th largest oil reserves owner in the world. This amount is about 10% of the world and 13% of Organization of the Petroleum Exporting Countries (OPEC) oil reserves. About 70% of reserves are onshore which are mostly located on the south-west part of the country and the biggest offshore reserve is located at the Caspian Sea in the northern part of Iran. The country's production used to be 5.5 million b/d in 1970's and reached to 3.7 million in 2011 after lots of variation. The economic sanctions decreased the production to 2.7 million b/d in 2013 and even less afterwards. After sanctions being lifted in 2013 the country rises to gradually recover its production level (US energy Information administration, 2015). Based on current estimations, Iran's crude oil reserves will be depleted in the next 94 years as the country both exports and consumes this carrier [24].

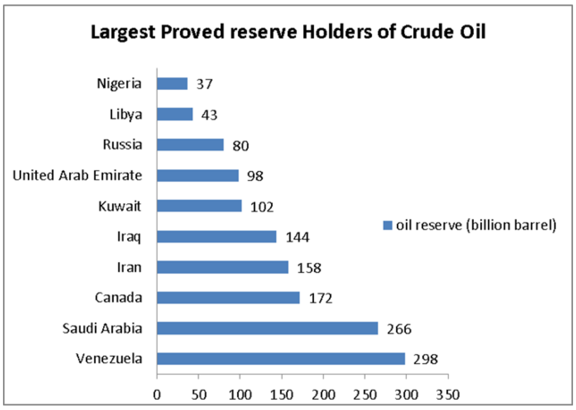

Figure 7- Largest holders of crude oil (billion barrel) – [36]

3.1.1.2 Gas

Iran owns the 2nd gas reserves in the world with proved reserves of about 1201 trillion cubic feet (tcf), which is 17.5% of the world and one-third of OPEC's natural gas reserves. South Pars gas field is the country's biggest gas reserve (40%) and is located in the Persian Gulf, in southern Iran. The natural gas production of the country was 8.1 Tcf in 2013 (US energy Information administration, 2017). Gas reserves are estimated to be depleted in the next 53 years The share of natural gas in energy supply increased from 44.63% in 2001 to 54.93% in 2008 [20].

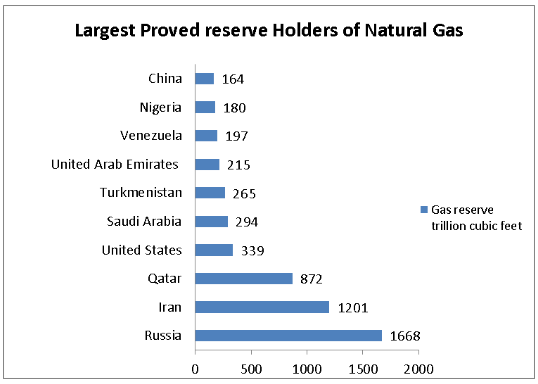

Figure 8- Largest holders of natural gas (trillion cubic feet) – [36]

3.1.1.3 Coal

This carrier accounts for a small portion of energy supply in Iran which is about 0.21% ,but in comparison to renewable energy resources it is still a considerable amount. The country currently holds 2.73 million tons coal reserve [20].

3.1.2 Renewable Energy Resources in Iran

Renewable energy resources are defined as those which can generate energy through a natural method and are not exhaustible such as fossil fuels or uranium [20] Although Iran owns large reserves of fossil fuels such as oil and gas, the process of investment in renewable resource started several decades ago. Despite of the national will and its development plan regarding renewable energy, the share of renewable energy resources in the total energy supply is still less than 1%.

Table 3- otal Renewable Generation (Installed) Capacity [33]

Cap (MW)	2006	2009	2012	2015
World	103149 4	124068 3	155980 2	19646 55
Iran	6631	7812	9924	12024

Table 3 illustrates that Iran owns only a small portion of renewable resources generation in the world. However, it is important to note the increasing capacity of the renewable sector in the country.

Table 4- Iran renewable energy generation capacity-Renewable Energy and Energy Efficiency [32]

No.	Power plant Type	Public sector cap (MW)	Private sector cap (MW)	Total (MW)
1	Wind	98.86	92.06	190.92
2	Solar (PV)	7.4	46.157	53.557
3	Biomass	0	10.56	10.56
4	Small Hydropowe r	62.4	10.85	73.25
5	Waste Heat Recovery	0	13.6	13.6
Total		168.6 6	173.22 7	341.88 7

Table 4 shows the composition of the renewable energy sector, excluding large scale hydro and nuclear energy resources. A big part of this capacity has been added in the last five years. In the recent years there were several discussions and analysis about the development of this sector. Price comparison with fossil fuels, the degree of energy security, high potentials for energy generation, possible environment results and their possible effects of renewable energy development were some of these discussions. In this regard, we will review different types of renewable energy resources separately. We will also consider hydropower and nuclear in this category.

3.1.2.1 Solar Power

Thanks to the more efficient solar panels, solar power and particularly Photo Volcanic (PV) has experienced an increasing expansion trend. Iran is a country that, due to its location on the Sun Belt, has a high potential of solar power. It has been estimated that is could be up to 3200 hours per year in the central parts. The potential of electricity generation varies in different parts of the country between 250 W/m2 to 540 W/m2 in the day time. It has been estimated that Iran has 1.7 million hectares (1.1% of the total land) with 270 W/m2 and 28 million (17.3%) hectares with 250-270 w/m2 (Azadi et al. 2017). This capacity is up to 2.5 times more than the average capacity in European countries. Since the diffusion and implementation of solar power in EU countries, with a lower potential and less solar radiation was significant, it shows to what extent Iran can increase its solar power capacity. Currently the country produces around 26 MW from solar power and 24 MW of this number started up in 2017 [32].

Table 5- Solar Energy Generation (Installed) Capacity [33]				
Cap (MW)	2006	2009	2012	2015
World	6496	23214	101538	223948
Iran		17	17	17

Based on the table 5, the solar power started in 2008 in the country but has stayed unchanged for several years. The country recently has provided a great support for solar power and has attracted a considerable investment in this sector. One of the highest tariffs in the renewable energy generation belongs to solar farm which is up to 0.121 EUR/kWh. This new incentive created new capacity of 44 MW and attracted 48 million EUR of foreign investment in solar power sector just in the last 12 months and this process continues with a progressive trend. Currently more than 120 MW solar power units are under the construction.

3.1.2.2 Wind Power

Iran owns many wind tunnels all around the country and the current electricity production is about 90 MW. By having the density of 275 W/m2 it has been estimated that the country has the potential of 6500 MW electricity generation from wind power. The main wind power stations in Iran are Kahak station located in Qazvin in upper center of the country with currently 55 MW, Manjil which located in northern part by the Caspian Sea with 71 MW and Binalood site located on the northeast, near Neyshabur with a capacity of 28.4 MW [37].

Table 6- Wind Energy Generation (Installed) Capacity [33]				
Cap (MW)	2006	2009	2012	2015
World	73281	150180	271713	416638
Iran	59	90	98	117

2.1 million hectares of the country (1.3% of the Land) has 8m/s or more, which is suitable for electricity generation (Azadi et al. 2017). Following Iran's Ministry of Energy incentive policies and import of new technology of 2.5 MW wind turbines, the new projects have now turned into mega projects. In comparison to solar power wind power is more limited. Despite the country's 14000 MW capacity in this sector, the economic condition for wind energy generation has agglomerated the capacity in particular regions of the country. This condition is generally based on the existence of continuous wind with a speed of 6.1 to 21 meters per second. In addition the construction of wind power units takes more time, is more complex and requires a higher technology [37].

3.1.2.3 Hydro power

Hydro dam construction is rooted and advanced in Iran. In addition to water supply and management and flood control, dams have played an important role in electricity generation and reduction of GHG in the recent decades. The country has targeted to reach 30,000 MW of hydroelectric generation in the near future [20].

Table 7- Hydro power Generation (Installed) Capacity [33]				
Cap (MW)	2006	2009	2012	2015
World	893190	993330	1090403	1207659
Iran	6572	7705	9808	11890

Comparing the capacity of hydro power with the country's total renewable generation capacity shows how large is the share of Hydro power. The hydro power technology is very environmental friendly with a high capacity of generation. However, the problem is that the initial capital investment of hydro power is very high since the facilities are usually located inside the dam structure. In fact this technology has a complementary relationship with dams and as a result has long construction period and requires high investment.

3.1.2.4 Nuclear Power

Although Iran faced many restrictions for development of nuclear power, it owns 3 nuclear power plants with the total capacity of

1400 MW. The biggest power plant is Bushehr, which is located in southern coast of Iran with 1000 MW capacity. It has been targeted for the country's nuclear sector to reach 7000 MW in the next 20 years [24]. Despite of its high electricity generation capacity, this technology has some proved adverse effects. Nuclear contaminations or explosions which sometimes turn into a disaster are a part of these issues. The disadvantages of nuclear power plants are doubled for Iran as the country deals with nuclear issues. Although the country has planned its network of nuclear power plants, the main issue is still providing them with nuclear fuel. The country owns some uranium mines but turning that to the fuel requires an enrichment process. Since enrichment process is very limited and under the IAEA supervision, the country faces issues to provide fuels with economic efficiency and reasonable price for the new units and even existing ones.

3.2 Worldwide and Iran Energy Price and Capacity Trend

Fossil fuels as the main resource of electricity power generation experienced many ups and downs in the price in the last decades. Oil, as one of the main role players in global energy price trends, was a part of these fluctuations.

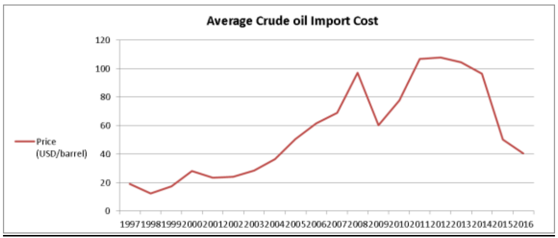

Figure 9- Average crude oil import costs (IEA Monthly oil price statistics, 2017)

Although the oil price has been recently decreased considerably, they are still not very cheap comparing to some types of renewable energy resources. What's more, fossil fuels like crude oil are not secure resources. For oil importing countries it carries the risk of price fluctuation and of being depleted for oil reserve owners. Unlike the irregular trend of oil price in the last decade the price of renewable resources was more reliable.

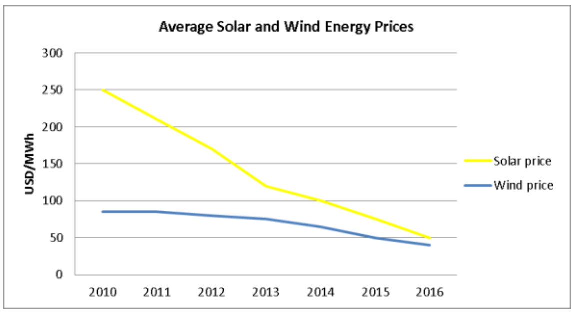

Figure 10- Average solar and wind energy prices [34]

Figure 10 illustrated the prices of wind and solar energy experienced a decreasing trend in recent years. Based on the data presented by the International Renewable Energy Association (IRENA), price of the wind power dropped to 40 USD/MWh in 2016, which is half of 2010, that used to be 80 USD/MWh. The price of solar power experienced a drastic decrease of one fifth and reached 50 USD/MWh in 2016.

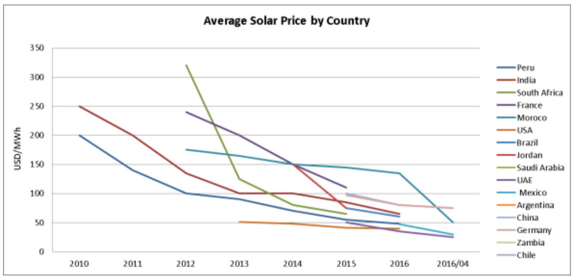

Figure 11- Average solar prices by country [34]

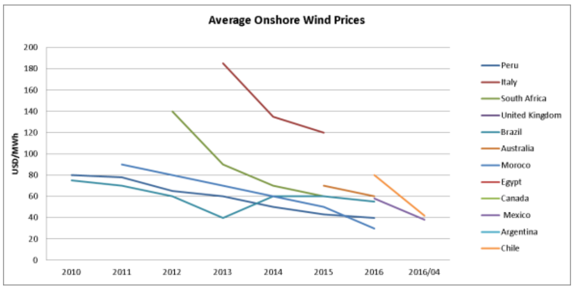

Figure 12- Average onshore wind prices by country [34]

The two above figures show that the global prices for wind and solar power might be even cheaper in some countries depending on their different elements and potentials. Due to the development blocks concept and the market widening mechanism, price is an important factor for diffusion of new carrier. Electricity as a secondary carrier is flexible regarding to the primary carrier. Price and efficiency are two major elements for the selection of electricity generation primary resources. As the price of renewable resources decrease, they can gradually diffuse and increase their share among primary resources for electricity generation.

The price is not a comprehensive measure when comparing between different types of energy resources. In economic analysis, particularly comparison of different types or resources of energy, we need a measurement in order to make a fair and balanced assessment. The measure, which implements for the cost of different types of electricity generation is called "Levelized Cost of Electricity" (LCOE) .In fact, this measure considers other factors that affect the generation costs, such as operation and maintenance, initial investment, and capital and fuel cost. The equation for this measure calculates the net present value of unit cost of electricity over the lifetime of the production asset. The formulation for this measure is as follows:

$$\mathbf{LCOE} = \frac{\text{sum of costs over lifetime}}{\text{sum of electerical energy produced over life time}} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(I+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(I+r)^t}}$$

I_t: investment expenditures in the year t

M_t: operations and maintenance expenditures in the year t

F_t: fuel expenditures in the year t

E_t: electrical energy generated in the year t

r: discount rate

n: expected lifetime of system or power station

The unit for LCOE is an international currency such as USD or EUR per kWh or MWh like EUR/ kWh. Although LCOE has some limitations such as ignoring time effects in connection with matching production to demand, it is still a transparent measure for comparing different types of energy generation (Islegen & Reichelstein, 2011). Energy Institution of America (EIA) announced LCOE for different resources of energy as follows:

Table 8- LCOE of electricity generation based on the power plant type (EIA, 2014)

Power Plant Type	Cost($/kWh)
Coal	0.095-0.15
Natural Gas	0.07-0.14
Nuclear	0.095
Wind	0.07-0.20
Solar PV	0.125
Solar Thermal	0.24
Geothermal	0.05
Biomass	0.10
Hydro	0.08

The above table shows the LCOEs of renewable resources converging to the fossil fuels. As long as LCOE is considered as a comprehensive cost for electricity generation, this convergence creates an opportunity for renewable resources to increase their share in comparison with fossil fuels.

Table 9- Renewable energy LCOE in Iran 2014 (Kaabi Nejad et al., 2016)

	Wind	Small Hydropower	Solar Thermal
LCOE ($/kWh)	0.0942	0.0940	0.2096

The above figure shows the LCOE of the main renewable resources in Iran in 2014.

There are several effective factors for cost reduction of renewable energy sector. Some factors, such as technology improvement associated with the development of renewable energy are general. Other factors, like access to finance, favorable environment, investor's confidence and existing policies to support renewable energy improvement are particular to each country [34].

Solar PV is an important technology regarding for increasing the capacity from 2 GW in 2009 to 222 GW in 2015, as well as for the price decrease of 80% between 2009 and 2015. The LCOE of this technology also decreased by 58% from 2010 to 2015 [34].The prices for onshore wind turbines also decreased between 10 to 45% in different countries by converging to USD 40/kWh [34].

Although the LCOEs of different energy carriers have recently converged, the trend for this measure will tend diversify based on the scenarios and action plans in the coming years.

Price scenarios in support of climate change prevention are targeted to increase the price of fossil fuels and make renewable resources competitive. These policies implement different methods such as charging higher taxes based on the volume of GHG emissions of different carriers.

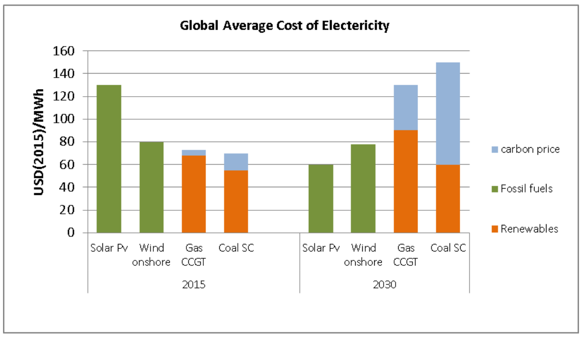

Figure 13- Global average levelised cost of electricity in 66% 2'C scenario [36]

In figure13 the reason for price increase scenario has been shown more clearly. While the renewable resources experiencing their decreasing trend and reach a lower level, the price of fossil fuels like gas and coal are predicted to increase considerably and, as a result, carbon pricing will double gas and triple coal's price.

In countries with abundant and cheap fossil fuels like Iran it might not be economically beneficial to generate energy from fossil fuels as their cost might be equal to or exceed in-country demand and export. However, it is not only about the cost, since the renewable resources bring sustainability and consistency. It is also stated that the price of renewable and nonrenewable carriers are increasing, but the fossil fuel costs will increase by a higher rate [5].

4. Drivers, feasibility and Methods of sustainable Transition to Renewable Energy Resources

4.1 Drivers

Beside the role of market mechanisms and price, institutions and regulations take an undeniable part in any socio-technical transition. They could perform as driver, barrier or facilitator for the transition process based on their nature. Among various ratified laws and regulations the country's commitments to UNFCCC for cutting GHG emissions and Iran's National Development plan are the most effective and well known examples in this regard. The recent increase of investment in renewable energy, particularly through foreign finance, was also another motive for the development of this sector.

4.1.1 Iran National Development Plan (NDP)

Iran's National Development Plan (NDP) is the country's main roadmap for development. It is a comprehensive 30 years plan for Iran's development divided into smaller 5 years plans. Although DNP targeted to develop clean tech resources in the energy sector, the large share of fossil fuels is still a barrier for these policies. The current NDP is targeted to ascertain the country's commitment with environmental protection and the reduction of the GHG emissions. The following articles are from Iran's 6th National Development plan which is currently running:

Article 48- 1% of the budget for ministry of oil development plans must be assigned to increase capacity and technology development of oil, gas, petrochemical and renewable energy

Article 50- Government is obliged to increase the share of renewable energy with the priority of private sector (domestic or foreign) by using maximum internal capacity of at least 55% of electricity power generation at the end of the plan period.

It has been targeted for the country to add 5000 MW renewable power units to its capacity which is currently less than 500 MW (Iran's 6th National Development Plan, 2016-2021).

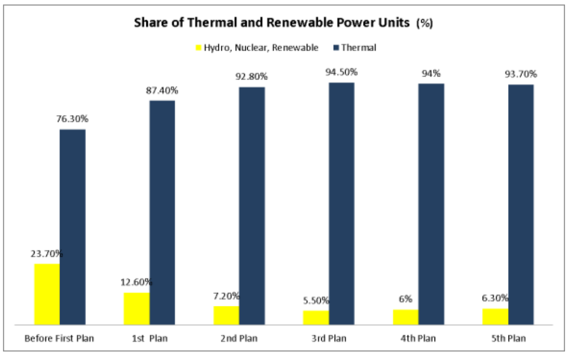

Figure 14- Accordance of actual and targeted electricity capacity in NDP [31]

Although government implemented different plans and policies for renewable sector, the above data shows high numbers and desired plans are not necessarily turning into reality. According to figure 14 the country's performance in thermal power units is acceptable, but the renewable sector is far behind.

4.1.2 Iran's Commitments to UNFCCC at Paris Conference 2015

Energy sector and the share of renewable and non-renewable resources are directly connected to the environment and economic sustainability. A problematic environment and an economy that relies on non-renewable energy resources are considered as a unsustainable condition that will never lead to economic development [5].

Iran's commitments to UNFCCC at the Paris climate change conference in 2015 to cut the GHG emissions between 4-12% shows the willingness of the country to favor the sustainable environment movement (United Nation Climate Change Conference, Paris 2015). As mentioned earlier increase in energy efficiency and implementation of renewable resources due to their low carbon emissions are two possible solutions for cutting the GHG emissions. Referring back to Iran's electricity sector, only 16% of electricity power generation belongs to renewable resources, of which the share of wind, solar and biomass is 0.2%, hydro-power 14.5%, and nuclear 1.3% [30].

4.1.3 Foreign and Domestic Investment in Renewable Energy in Iran

Despite of Iran's energy sector infrastructure and design, few Iranian and foreign countries have invested in the country's renewable energy sector. These projects include a variety of renewable energy projects like solar or wind farms, as well as other type of projects in different parts of Iran.

Table 10- Installed Renewable Energy Power Units in Iran [32]

Item	Power Plant	Governmental Capacity (MW)	Non-Governmental Capacity (MW)	Total (MW)
1	Wind	98.86	92.06	190.92
2	Solar (PV)	7.4	46.157	53.557
3	Biomass	0	10.56	10.56
4	Small Hydropower	62.4	10.85	73.25
5	Waste Heat Recovery	0	13.6	13.6
Total		168.66	173.227	341.887

The above table shows the installed capacity of renewable power units recorded by Iranian renewable energy organization, SATBA. Based on the data, a considerable part of the above mentioned capacity has been constructed in the last 2 years, including 54 MW wind and 45 MW solar (PV). These new projects attracted EUR 125 million investments to the renewable sector, including about EUR 48 million foreign investments. Among the recent built units, the foreign investment was significant, particularly in solar power units.

Table 10 shows Iran's renewable market development is not limited to constructed units, and a big new capacity is on the way. Although the 1089 MW wind and 932 MW solar power purchase agreement are small numbers comparing to the country's potential, they are still large numbers compared to Iran's renewable energy sector scale.

Table 11- Companies with renewable power purchase agreement (PPA) in Iran [37]			
Item	Power Plant	No. of Companies	Capacity (MW)
1	Wind	21	1089.15
2	Solar (PV)	76	932.24
3	Biomass	3	6
4	Small Hydropower	8	8
5	Waste Heat Recovery	4	60
Total		168.66	173.227

4.2 sustainable transition of Iran electricity power to renewable resources

The review of Iran's energy sector, particularly electricity sector and the composition of primary energy resources, contrasts with the concept of energy sustainability. The high ratio of fossil fuels might cause insecurity and instability in the sector in the long-run. By defining the gap between the country's electricity sector and sustainability, we will reach the first step of a transition to renewable resources, which is feasibility.

4.2.1 Feasibility of sustainable transition to renewable resources

The most important fact in energy sustainability is the conformity of consumption and generation of energy (McKay, 2009:103). The calculation for the energy generation capacity and feasibility are complex and require multi-dimensional scientific studies. In this part we will make some simple calculations based on the country's data and potentials in order to show to what extent the renewable energies can substitute the fossil fuel resources in case they reach their maximum potential capacity. Due to the high potentials of solar and wind energy in comparison to other renewable energy resources in Iran, we only focus on these two resources here as renewable options.

Wind

As mentioned earlier 1.3% of Iran's land including 26 regions (45 sites) is economic for wind energy generation. This potential is capable of creating 6500-14000 MW capacity of wind power which could cover 8.5-18% of the current electricity capacity (76427 MW).

Solar

The solar power potential is between 2.8 and 5.4 w/m2 per day and the area per person is 18,350 square meters (1,483,375 km2/ 80,836,699) so considering the minimum capacity per person/m2:

2.8W/m2 × 18,350m2 per person = 51.38 kWh/d per person

Electricity consumption per capita is 2985 kWh per year or 8.15 kWh per day. If we consider the above calculated capacities the potentials are also enough for almost five times more consumption in the case of growth in electricity demand. In addition to the generation capacity, these potential seems enough for meeting the commitments of increasing the share of renewable resources to 65% and cutting emissions up to 12% to UNFCCC.

Considering 28 million hectares with the minimum generation capacity of 2.8 w per m2, gives us the number of 784,000 MW as the capacity of the country for solar power generation. As the renewable energy experts state, PV power units with 100 km length and 100 km width of solar cells is enough to meet the country's electricity demand.

This was just simple calculations to examine the capacity feasibility of transition of the electricity power generation to renewable resources while many other technical, economic and social factors are effective for this process.

4.3 Methods for sustainable transition of electricity sector

4.3.1 Carbon Pricing

One of the effective methods for making renewable energy resources competitive and facilitating renewable energy transition is carbon pricing. There are different opinions about the amount and trend of carbon taxation.

While some economists argue that it should be a decreasing value, others state that due to the accumulation of carbon dioxide, it must increase up to a certain level and start to decrease at the time that fossil fuel reserves are about to exhaust. For instance the model implemented in 1990's in European countries was charging $3 per barrel of oil and increase $1 annually until 2000 [10].

Converting carbon pricing from an agreement into a law requires the intent of the countries' jurisdiction system. While some countries like Sweden are pioneer in carbon pricing methods like charging 126 USD/tCO2e other recently joined economies such as Mexico are currently charging 1 USD/tCO2e (World Carbon Price Watch, 2017).

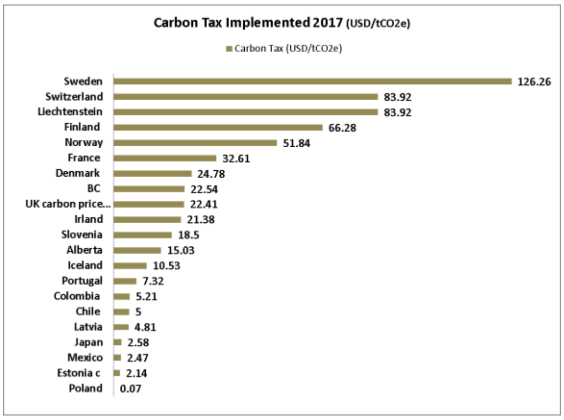

Figure 15- Carbon tax implemented (USD/tCO2e)-[38]

The CO2 emissions of different types of energy careers are different. It is proven that the fossil fuels are the main sources of CO2 emissions. For a better comparison of emissions of different energy carriers, we will consider their CO2 volume of emission (grams) unit for every unit of energy (MJ). As it can be seen below the CO2 intensity varies for different sources of energy.

Carbon pricing systems are effective for emissions reduction by reducing the demand for energy and shifting the economy to clean energy resources. The major problem with ETS is price vitality as its allowance is determined in market based on the energy demand and supply mechanism.

Table 12- Co2 emission factors for different fossil fuels, gram Co2/MJ [1]

Coal	92
Oil	74
Natural gas	56

Since the carbon price volatility imposes costs to emission cutting programs, like carbon taxing, programs with fixed prices are more recommended when compared to cap and trade (ETS) methods. Carbon taxes are more effective environmentally comparing to cap and trade system. While taxes are additive and effective for mitigation plans, prices in cap and trade might have severe cap and become ineffective as a result (IMF, 2011).

Carbon taxation not only carries the advantages of motivating the shift to alternative resources, but also helps the conservation of environment, increases government revenue and enhances socially efficient income. However, it also might cause some disadvantages such as a shift in production, imposing heavy administration costs, increasing the possibility of costs growth and supporting hidden operations (IMF, 2011).

The table below shows that increasing the CO2 pricing is one method for supporting the global agreement on emission reduction. This mechanism makes renewable resources competitive as it increases the cost of fossil fuels. This prediction also shows that the carbon prices are relatively low for Non-OECD and developing countries, like Iran, based on the nature of their economy and energy sectors.

Iran has already established some legal articles regarding to pollution taxes in NDP but they do not seem binding. Additionally, the decision making reference in the mentioned articles are not a country wide system and decisions could be made by local judiciary. In fact, it is a penalty system rather than a carbon pricing system. Applying a real carbon pricing system requires localized scientific calculations based on in-depth studies. Recently, Iran's government has ratified a law named green tax. It is predicted that government charges 0.5-1.5% income taxes on polluting units which do not obey environmental standards (green tax and accounting).

Table 13- Summary of CO_2 prices on the 66% 2C Scenario (USD/tCO_2) – [36]

	2020	2030	2040	2050
OECD countries	20	120	170	190
Major emerging economies*	10	90	150	170
Other regions	5	30	60	80

- Includes People's Republic of China, Russian Federation, Brazil and South Africa

4.3.2 Energy subsidy

Iran's energy sector, which is controlled by a government monopoly, receives the highest subsidy amount in the world. This subsidy is worth around $82 billion and consists of 16% of the country's GDP [24]. In addition to the abundance of fossil fuel reserves, which keeps them at low prices in the market, the subsidy that the government assigned to them is making them even cheaper. This process takes the competitiveness of renewable resources away. In the recent years, the government has planned to reduce the allocated subsidy of fossil fuels gradually and let the prices converge in their real level.

For renewable energy promotion, factors such as the subsidy for equipment purchase, the reduction of interest rates, a subsidy for O&M, higher selling prices, or putting a constraint on energy supply mix could be used. One common subsidy tool economies use to make renewable energy sector more attractive with higher selling prices is feed in tariffs (FiTs).

For conducting FiTs policies, Iran Renewable Energy Organization (SATBA) settled a 20 years purchasing power agreement (PPA) with guaranteed tariffs and their annual adjustment

Table 14- FiTs for Iran renewable electricity generation [37]

Power Plant Technology Type			FiTs (EUR per kWh)
1	Biomass	Landfill	0.064
		The anaerobic digestion of manure, sewage and agriculture	0.096
		Incineration and waste gas storage	0.090
2	Wind Farm	above 50 megawatt capacity*	0.088
		with the capacity of 50 megawatt and less	0.109
3	Solar Farm	above 30 megawatt capacity*	0.083
		with the capacity of 30 megawatt and less	0.104
		with the capacity of 10 megawatt and less	0.127
4	Geothermal including assessment and excavation		0.127
5	Waste Heat Recovery (WHR) from industrial process		0.075
6	Small Hydropower (with the capacity of 10 MW)	Installation on the rivers and side facility of dams	0.054
7		Installation on the pipelines	0.039
8	Fuel Cell System		0.128
9	Turbo Expanders		0.041

Quota capacity for the wind and solar farms are determined by the compliance of paragraph 8 of this directive.

for the money devaluation based on the Euro exchange rate and internal inflation. They established a system benefit charge (SBC) proposed by the World Bank in 2010 that is in the amount of 0.0015 USD per kWh (except rural consumers) charges on electricity bills. These charges were USD 334 million of which 50 % is assigned to the development of renewable energy. This is also mentioned in article no. 5 of support of electricity industry law. The factors they consider for FiTs are Internal Rate of Return (IRR) and payback period. If the investors use a low interest loan, SATBA will consider it as a subsidy and deduct it from their FiTs [37].

Methods and policies for renewable transition are necessary as the matter of investment constraints and price implications. Even high economic potential for renewable energy generation is not a guarantee for the development of this sector. Based on some policy scenarios renewable resources should enter the market when the producers can at least cover their marginal production cost. They state solar power is independent from availability of oil. It might delay first entering the market, but once in, it gets to the same path as oil consumption, and later they will reach same level of peak price. Through the transition process natural reserves coexist rather than override each other (Amigues et al. 2015).

4.3.3 Renewable Energy Tenders

The recently organized tender of different countries for constructing their new renewable energy projects is named "Auction". These auctions increased the global renewable energy installed capacity and reduced the prices. In solar power sector the capacity increased from 2 GW in 2012 to 222 GW in 2015 and the solar PV LCOE decreased 58% from 2010 to 2015. Prices decrease varies in different countries between 10-45% late 2016. The mentioned method is currently more common comparing to others such as feed- in tariffs and is based on particular determinants. A country's specific condition and finance accessibility, conductive environment and investor's confidence, its policies in support of renewable energy, and design factors for auction are the main determinants [33]. Auctions, like other transition methods, will affect the renewable energy price, which is effective on the supply and demand mechanisms.

5. Data & Method

5.1 Methodology

In order to conduct this research the qualitative method has been chosen as it is the best fit for complex social problems. As the focus of qualitative research approach is on the quality or meaning of experience, it is helpful for defining a socio-technical mechanism. The interpretivist approach and the aim of qualitative method for describing and discovering make it a proper method for a transition process that includes many complex elements. This flexible approach is also the best fit for an evolving or emerging concept like the aimed theoretical concept of our research.

In addition, the main advantages of qualitative research are exploration, description and interpretation. Exploration is about the understanding of patterns, phenomena, while description completes this understanding. The interpretation tries to make sense what is going on.

Case study is a suitable qualitative method to study a process and is also flexible for a research design. Case study is an empirical inquiry that investigates a contemporary phenomenon with its real life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2003 p 16).The interviews for gathering primary data, archive records and documents for organizing the analytical criteria, are the best instruments for conducting a case study research (Yin, 2003, p 87) The focused interview is a respondent interview for a short period of time and it is semi structured for giving some degree of freedom to the interviewee (Yin, 2003: 90).

The reason for picking Iran as the case study is that the country has big reserves of fossil fuels like other countries in the region. But the case would be more interesting when we have focused on the country's solar power, which also has a very high potential and thus provides a high motive for studying a socio-technical transition in the energy sector. The aim selecting three perspectives of the investor, contractor and the government side of the sector, is to find a more practical pattern for transition and validate the different perspectives at the same time.

In order to create a high quality case study research design we should set the research based on 4 main principles. First, construct validity, which could be organized by implementing different sources or evidence, or a chain or collection of them. For internal validity of the research pattern matching, explanation building and logic models have been used. External validity requires theory in single case research design and replication logic in multiple cases (Yin, 2003 p 29). For this regard, the same set of semi conducted questions have been asked to two CEOs of the investment companies in Iran's solar power industry, as well as to the head of strategic and economic studies department in Iran Renewable Energy and Energy Efficiency Organization (SATBA) to review the case from two different perspectives. Reliability could be built by a case study protocol (collection) or database.

The lack of up-to-date data from valid resources, like IEA or IRENA, and the impossibility of conducting an interview with MAPNA, the biggest company in the wind power industry in Iran could be counted as the limitations of the project.

6. Results & Discussion

According to the present analysis, we found that, like other economics scarcities, resource limits, energy security in the long run, as well as environmental issues are the main drivers of Iran's transition to renewable resources. Although the country has an abundance of fossil fuel reserves, the use of them as an income resource will eventually deplete them. It would be a threat for the country's energy security in the long run. The related articles in the country's National Development Plan (NDP) for increasing the renewable resources share might confirm this fact.

Iran's energy sector as a socio-technical system includes important actors like the Ministry of Energy and SATBA, institutions like NDP and different related material and knowledge. Iran's energy sector transition started in the first decade of 21st century with protected small size renewable power units as pilot units. This niche in the sector is still protected by the government by implementing different mechanisms such as FiTs, guarantees and exemptions. Landscapes such as Iran's high potential for renewable energy generation, NDP and commitments to UNFCCC are helping to niches to overcome barriers like low price and abundant fossil fuels. The mentioned niches by implementing the facilities of the landscape try to put pressure on the current regime, which is basically based on the fossil fuels for electricity generation to gradually transform it.

At the macro level, the energy sector is dealing with three major development blocks. Since still a big portion of transportation and electricity generation consumes fossil fuels as the primary resource, ICE-Oil development block is still dominant in these sectors. Although ICE performed as the market suction tool, due to the country's big reserve of oil and gas, pipelines and oil tankers were not very effective for price decrease and its respective diffusion. But on the other side, an increase in the final service of energy generation as a secondary carrier shows that the electricity block has experienced a large growth. This sector benefited from a wide electricity network as the market suction and big power plants with high capacity and high voltage transformation functioned as market widening tools. The country's increasing trend of electricity consumption might show the ICE block is under development and is yet inefficient. In addition PC, Mobile and electric cars, as market widening mechanisms of this block, are not yet developed in the country.

Although the country has a high potential for transition of energy sector to renewable resources, the cheap fossil fuels and under developed infrastructures in electricity and ICT sector are big issues in this regard. Carbon pricing systems, subsidies and institutional support are reasonable methods for protection and development of the renewable sector in Iran. These methods take the environmental costs of fossil fuels in to the consideration and make fossil fuel prices competitive for consumption and feasible for generation. The country has already developed policies including: high selling prices such as FiTs or constraints on energy mix in NDP and other regulations, which benefit from legal authority and have resulted in the development of renewable energy sector, particularly in solar power.

One big issue in the transition process is whether the country targeted to generate renewable energy or acquire renewable energy technology and industry. Based on the current policies of Iran's Ministry of Energy the country is targeted to localize the industry rather than just generating renewable electricity. Iranian model for energy sector transition is applicable to other oil producing countries with similar structure and potential, as long as they are willing to have renewable energy industry. Additionally, currently energy efficiency comes prior to renewable energy generation policies in the country.

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7. Conclusions

Iran as a big owner of natural resources and a vast landscape, owns variable resources for energy production. Despite of these huge reserves, the country's development plan, international commitments for the reduction of GHG emissions and long term perspective of finite fossil fuels, provide the motivations for the transition to clean energy resources. Regardless of various plans and institutional support for renewable resources, the country's path dependency and trajectories for investment in the oil industry, the cheap resources of fossil fuels, the lack of infrastructures and technology are the main barriers for this transition. Decreasing price trend of renewable energy resources, CO2 pricing, renewable energy subsidization and energy mix constraints are major solutions for the price side. These methods facilitate domestic and foreign investment coinciding with technology import, which creates the opportunity for the development of the renewable energy sector and the process of transition to these clean resources. Institutions and their respective policies are the main domestic role players in this socio-technical transition. In Iran they have agreed on acquiring the renewable energy technology during transition process rather than having renewable electricity power.

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References

Books :

[1] Kander, A., P. Malanima and P. Warde (2013). Power to the People - Energy in Europe over Five Centuries, Princeton University Press

[2] MacKay, D. (2009) Sustainable Energy – without the hot air, UIT Cambridge Ltd, available online: https://www.withouthotair.com

Articles :

[3] Amigues, J.P., Alain Kama A.L., and Moreaux M. (2015). Equilibrium Transitions from Non Renewable Energy to Renewable Energy under Capacity Constraints: European Community's Seventh Framework Programme

[4] Azadi P., Nezam Sarmadi A., Mahmoudzadeh A., Shirvani T. (2017). The Outlook for Natural Gas, Electricity, and Renewable Energy in Iran: Working Paper 3, Stanford Iran 2040 Project, Stanford University

[5] Bakhoda, H., Almassi, M., Moharamnejad, N.& Moghaddasi, R., Azkia, M. (2012). Energy production trend in Iran and its effect on sustainable development: Elsevier, Renewable and Sustainable Energy Reviews 16 1335– 1339

[6] Berkhout, F., Angel, D., and Wieczorek, A.J. (2009). Sustainability transitions in developing Asia: Are alternative development pathways likely?: Technological Forecasting & Social Change, vol 76, no 2

[7] Dahmén, E., (1989). Development Blocks in Industrial Economics: Industrial Dynamics, Kluwer Academic Publisher, PP 109-121.
[8] The Economist (1977), What Dutch disease is and why it's bad, , 26 Nov, P 82-83
[9] Farzanegan, M.R & Markwardth G. (2009), The Effects of Oil Price Shock on Iranian Economy: Energy Economics 31, 134–151
[10] Farzin & Tahvonen, (1996). Global Carbon Cycle and the Optimal Time Path of a Carbon Tax: Oxford Economic Papers 48, 515-536.
[11] Fardmanesh, M. (1991). Dutch Disease Economics and the Oil Syndrome: An Empirical Study: World Development, Vol. 19, No. 6, pp. 711-717
[12] Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study: Research Policy 31 pp. 257-1273
[13] Geels, F.W. and Schot, J.W. (2007). 'Typology of sociotechnical transition pathways, Research Policy, 36 (3), pp.399-417
[14] Heal, G. & Hallmeyer, K. (2015). How lower oil Prices impact the competitiveness of oil with renewable fuel: Columbia SIPA, center on global energy policy
[15] Hoel, M. (1992). Emission Taxes in a Dynamic International Game of CO2 Emissions: Resource and Energy Economics, Volume 15, Issue 1, March 1993, Pages 51-70.
[16] Islegen, Ö. & Reichelstein, S. (2011). Carbon Capture by Fossil Fuel Power Plants: An Economic Analysis: Management Sci. paged 57, 21
Jacobsson, S. & Bergek, A. (2004). Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology: Industrial and Change, Volume 13
[17] Kaabi Nejadian A., Separi F, Barimani Varandi M. and Khaje Samakoosh M.R. (2016). Survey of Renewable Electricity Tariffs in Iran, Springer International Publishing Switzerland A. Sayigh (ed.): Renewable Energy in the Service of Mankind, Vol II, pp 137-144
[18] Konrad, K. A., Olson, T. E., Schöb, R. (1994). Resource Extraction and the Threat of Possible Expropriation: The Role of Swiss Bank Accounts: Journal of Environmental Economics and Management. 26: 149–162
[19] Markard, J. (2012). Sustainability Transitions: An Emerging Field of Research and Prospects: Research Policy, pages 955-967
[20] Mohammadnejad, M., Ghazvini, M., Mahlia, T.M.I., Andriyana A. (2011). A review on energy scenario and sustainable energy in Iran, Renewable and Sustainable Energy: Elsevier, Reviews 15 4652– 4658
[21] Monaghan, A., Eames, M. and Steward, F. (2008). The feasibility of systems thinking in sustainable consumption and production policy: a report to the Department for Environment, Food and Rural Affairs, London: DEFRA.
[22] Moomaw, W.R., Verkooijen, P. and Aggrwal, P. (2017). The Future of the Paris Climate Agreement: Carbon Pricing as a Pathway to Climate Sustainability, The Fletcher Forum of World Affair, No. 41 p 69
[23] Røed Larsen, E. (2009). Escaping the resource curse and the Dutch Disease? when and why Norway caught up with and forged ahead of its neighbors: Statistics Norway, Research Department
[24] Tofigh , A.& Abedian,M. (2016). Analysis of energy status in Iran for designing sustainable energy roadmap: Elsevier, RenewableandSustainableEnergyReviews571 296–1306
[25] Yin, Robert K. (2003). Case Study Research: Design and Methods: Applied Social Research Method Volume 5, Series, SAGE publication.

Data & Report:

[26] International Monetary Fund (2011). Promising Domestic Fiscal Instruments for Climate Finance, Background Paper for the Report to the G20 on―Mobilizing Sources of Climate Finance (pdf) Available at:
http://www.imf.org/external/np/g20/pdf/110411b.pdf
[27] International Renewable Energy Agency (IRENA) (2017). Renewable capacity statistics, [pdf] Available at:
http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Capacity_Statistics_2017.pdf
[28] Iran's Department of Environment (2017). Iran green tax, available online at:
https://en.doe.ir/Portal/Home/ShowPage.aspx?Object=News&ID=ed24cfca-d148-47f7-8c17-

508681497e38&LayoutID=663d2f2d-4932-4f68-b93c-7e335d8d6a59&CategoryID=6b8285b9-9521-4150-bd9c-c67d476ab179&SearchKey
[29] Iran's Government (2016), Iran's 6th National Development Plan available online at:
http://dolat.ir/detail/281959
[30] Iran Ministry of Energy (2016). Electricity Industry Detailed Statistics, (March 2016-March 2017), available at:
http://isn.moe.gov.ir/getattachment/260f0530-dc7a-476a-a756-aa8176395352/-امار-تفصيلي-صنعت-برق-ايران-ويژه-مديريت-راهبردي-(۱)
[31] Iran Ministry of Energy (2015).48 years report of Iran electricity industry (1966-2014), available online at:
http://isn.moe.gov.ir/getattachment/77506937-5725-4e1b-b704-0908ffbbb0ac/-گزارش-چهل-و-هشت-سال-صنعت-برق-ايران-در-ايينه-ي-امار
[32] Iran's renewable energy resources, (2017), Iran Renewable Energy and Energy Efficiency Organization (SATBA), available online at:
http://www.satba.gov.ir/en/home
http://www.satba.gov.ir/suna_content/media/image/2016/07/4687_orig.pdf?t=636036605261343750
[33] IRENA (2016). The Power to Change: Solar and Wind Cost Reduction Potential to 2025, available online at:
http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf
[34] IRENA (2017). Renewable Energy Auctions: Analysing 2016 , [pdf] available at:
http://www.irena.org/DocumentDownloads/Publications/IRENA_REAuctions_summary_2017.pdf
[35] Lazard's levelized cost of energy analysis, (2016). available at:
https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf
[36] OECD/IEA and IRENA (2017). Perspective for the energy transition, investment needs for a low-carbon energy system, [pdf] available at:
http://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf
[37] SATBA (2017). Installed renewable energy power plants situation up to end of AUG 2017 in Iran available online at:
http://www.satba.gov.ir/en/investmentpowerplants/statisticsofnongovernmentalpowerplants
[38] The World Bank Group (2017). World Carbon Pricing 2016, [pdf] available at::
http://www.ecofys.com/files/files/world-bank-group_ecofys-carbon-pricing-watch_160525.pdf
[39] US Energy Information Administration (2017). International energy data and analysis, available online at:
https://www.eia.gov/beta/international/country.cfm?iso=IRN
[40] U.S. Energy Information Administration (2017). Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook, available at: https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf