Energy Security in a Resource-Rich Economy: Case of Iran

Reza Hafezi and Amirhossein Souhankar

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Abstract

Energy security is an evolving concept that is defined based on national potentials, needs, and concerns. The concept is defined differently from the viewpoint of importers and exporters (resource-rich economies), and it is still evolving and dynamically changing aligned with energy market revolutions and crises. Most energy security reports investigated energy importers' concerns since the history showed fluctuations from the supply side initialize remarkable changes on the demand side, as the system behaves chaotically. This chapter studies energy security from the perspective of resource-rich economies and shows how it is going to be an emerging challenge in near future. A new framework to map

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F. Taghizadeh-Hesary, D. Zhang (eds.), *The Handbook of Energy Policy*,
https://doi.org/10.1007/978-981-16-9680-0_4-1

energy security is proposed to investigate it holistically. The framework is broken down into components, and they were discussed. We believe existing policymaking paradigms cannot answer future challenges and therefore need to be revised. Also, during the time and due to technological advancement, development of new energy sources, and environmental concerns, energy security of fossil fuel resource-rich nations is challenged, an issue that has not been experienced before. In this chapter, new dimensions of the energy security concept are discussed. Also, Iran as a resource-rich economy has been investigated and an initial set of policies are proposed aimed to address emerging energy security-related challenges in the case of resource-rich economies. However, it seems that energy security will be an open question that needs active cooperation from both supply and demand sides.

Keywords

Energy security · Energy policy and foresight · Sustainable development · Resource-rich economies · Future energy market · Iran

Introduction

Energy security is an evolving concept that is developing dynamically over time (Hafezi & Alipour, 2021). As Sovacool (2011) and Hafezi and Alipour (2021) showed, different viewpoints and challenges dramatically influence the way one conceptualizes energy security. However, Sovacool marks that although different references provide different descriptions, they are similar in some ways (Sovacool, 2011). To sum up, generally energy security attempts to cover the following aspects:

1. Technical feasibility, to ensure energy production and providing services technically.
2. Economic affordability, to ensure access to energy sources at a meaningful price to the public.
3. Environmental protection, to reduce and eliminate environmental side effects originating from energy sources.
4. Energy reliability, which ensures sustainable access to energy.
5. The security of supply mostly refers to providing appropriate infrastructure and distribution power systems to maintain electricity supply at a normal level.

Historically, after the 1973 energy shock, energy security has attracted attention and officially added to the energy policy vocabulary (Hafezi et al., 2017), although it has been considered before. But, 1973 played as a game-changer, which initializes oil price jumps over the second half of the 1970s; the decade ended with Iran's revolution (in 1979) that also magnified oil prices in international markets. Figure 1 presents OPEC oil price (per barrel) over the time from 1960 to 2021.

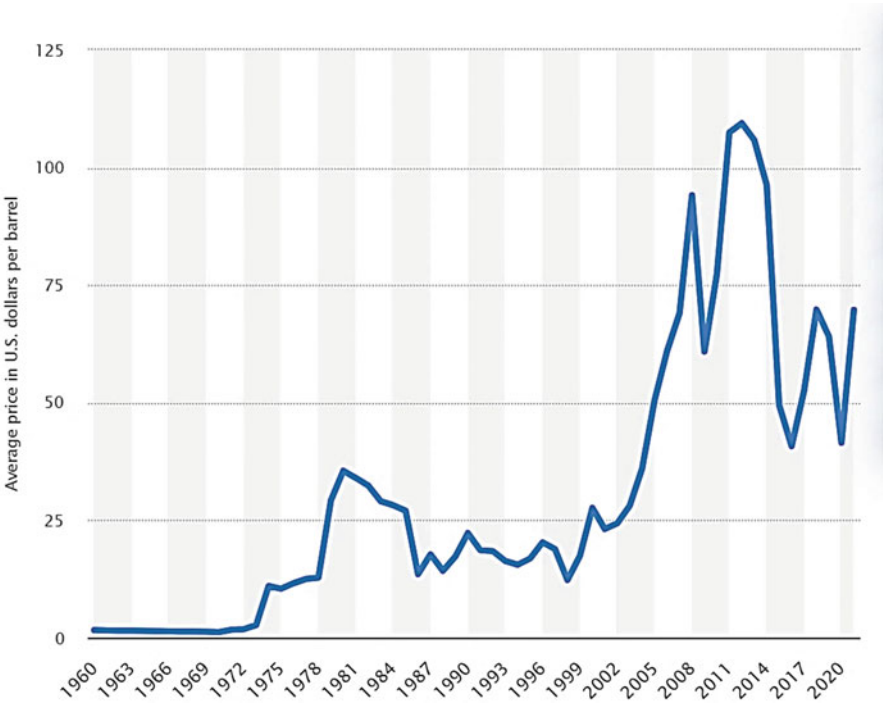

Fig. 1 Average annual OPEC crude oil price from 1960 to 2021 (Sönnichsen, 2021)

As shown by Fig. 1, the need for more energy and a modern-world lifestyle upset the balance of energy supply and demand which caused the early 2000s oil price increase, and over two decades two black swans, global economic crises, and the COVID19 pandemic caused energy price tsunamis one ascending and the other descending. In addition, economic growth correlated with energy consumption positively (Saidi & Hammami, 2015) which means energy prices directly influence national gross domestic production (GDP) value. Also, a lack of sufficient energy may cause social unrest and public dissatisfaction. As a result, guarantying energy security is crucial for governments to maintain economic and social stability. This chapter argues that there is no single prescription and the differences increase when we compare supply and demand-side countries with different present and future challenges.

Let us challenge three interlinked and sometimes conflicted concepts, (1) sustainable development, (2) energy security, and (economic) growth. Sustainability is generally defined as "satisfying meeting current needs without sacrificing future well-being through the balanced pursuit of ecological health, economic welfare, social empowerment and cultural creativity" (Thiele, 2013). Fossil fuels are overused, and it will take millions of years to produce new resources. It is a fact that we will run out of oil soon. Burning fossil fuels releases carbon stored in them that drives climate change. Emissions will disrupt human activities, requiring more

resources to keep the current lifestyle. These events overthrow sustainability. However, energy security in underdeveloped regions aimed to eradicate energy poverty at a rational price, which may cause environmental side effects.

Reviewing the existing background shows that in the field of planning, growth mostly refers to economic aspects (economic growth) that is evaluated based on aggregate production and good in an economy. However, social and environmental concerns which were initialized based on economic indicators (i.e., national targets) challenged the growth dramatically. Moreover, in the very early decades after the industrial revolution, the concept of economic growth was measured based on the present value without considering the future consequences. Furthermore, leveling up energy security conflicts with economic indexes where policymakers try to reduce inequality or decide to develop renewable power plants in a fossil fuel-rich region to reduce pollution and protect the environment. So, we are facing three interlinked and kind of conflicting concepts that need action to achieve an equilibrium state. Figure 2 graphically shows interactions between sustainable development, economic growth, and energy security which are entangled strongly.

To approach the desired future, we need to satisfy all three sides simultaneously. This issue will be examined in this chapter, especially from the side of suppliers in the energy market. So, in this chapter, we will illustrate the difference between energy security from energy importers to energy exporters. Then with emphasis on resource-rich countries, policy implications and recommendations are proposed to guarantee and enhance energy security levels in an energy exporter country which mostly are listed under developing economies with a greater slope in energy demand than in developed countries.

The concept of energy security rose from the demand side, but in its modern conceptualization, energy security is a challenging supply side of the energy markets. Since energy accessibility, energy poverty, and affordability are not generally

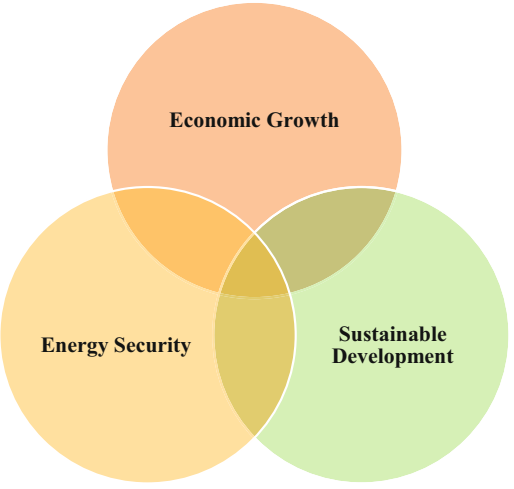

Fig. 2 The interconnection between sustainable development, economic growth, and energy security

an energy supplier's concern (at least in the short-term), they can commonly enhance energy security via supporting diversification, smart grid development, and radical change to a diversified multiproduct economy (to reduce the effect of the energy-driven economy). The concept of energy security is challenged in this chapter based on resource-rich economies' needs and interests. It was noted that energy security is a concept that has to be defined based on national potentials, challenges, visions, and actions.

Contributions can be investigated from both practice and theory. From the practical side, this chapter is one of the first studies that deal with energy security in a resource-rich economy, since changes are emerging for energy exporters, especially for fossil fuel providers such as Iran, Iraq, Saudi Arabia, etc. in the carbon tax era. From the technical side, here new characteristics are investigated and theorized based on two major aspects (1) socio-environmental characteristics and (2) Econo-political characteristics and a minor aspect, technological characteristics.

The Concept of Energy Security Varies on Supply and Demand Sides

In most references, energy security concepts and improvement strategies are investigated regardless of countries' positions in the global energy markets, nor their potential and challenges. Although, most nations are categorized under importer countries and the concept of energy security originally emerged referring to access to affordable energy, modern world challenges, especially environmental and social concerns, also challenged energy supplier countries (the same point has been mentioned by Karatayev and Hall (2020)).

Understanding these differences is critical, especially in the current situation, to address the international concerns (i.e., poverty, inequality, climate change, etc.) which need the commitment and cooperation of all countries, given their position, challenges, and potential, so that national economies and energy security are not compromised.

Most published literature on energy security is designed to address issues about resource availability focused on resource-poor and energy-importing economies (Hafezi & Alipour, 2021; Karatayev & Hall, 2020). On the other hand, it seems that unlike resource-poor economies, energy security in resource-rich economies drives by external shocks like environmental programs and obligations, political pressures such as international sanctions and bargaining power of energy importing nations, etc. (Nepal & Paija, 2019).

In addition to the concept of energy security which can be varying for energy importers and exporters, there is no accepted set of indicators to assess energy security. Although the inconsistent definition can result in inconsistent indicators, some researchers attempted to provide a general macro view. For instance, Karatayev and Hall, based on Caspian region energy exporters and previous studies, have detected three main dimensions containing (1) resources and dependency, (2) intensity and sustainability, and (3) cost and poverty (Karatayev & Hall, 2020).

Under each category, a series of indicators have been generalized. Here the initial objective is to determine energy security features based on a prospective study, instead of a historical analysis. We believe that the future will bring new challenges and trigger paradigm shifts that can influence resource-rich economies extensively, such as environmental costs and development limitations due to (mostly environmental) International obligations. As an example, among Caspian Sea economies, Iran has the best situation in terms of energy security with a growth of about 80% from 1991 to 2018. Table 1 summarizes energy security values for Azerbaijan, Iran, Kazakhstan, Russia, Turkmenistan, and Uzbekistan comparing 1991 assessments with 2018.

As has been shown in Table 1, most Caspian Sea region resource-rich economies recorded improvements. Only Uzbekistan experienced a high reduction rate which can be linked to the reduction in the country's oil production volume. Referring to Table 1, resource-rich countries such as Iran should not worry about the future of energy security. But weak signals reveal that we are facing a systematic change that contains the following:

1. Electrification trends: Based on reported trends and projections of demand, electricity is going to increase dramatically (BP, 2020).
2. Availability of new technologies: Significant technology price decrease made technology diversification feasible.
3. Emission tax: This emerging driving force will affect resource-rich economies' competitive advantages heavily.
4. Social movements: which are derived from environmental concerns.
5. Nexus challenges: Energy-water-food nexus is an emerging challenge that can affect energy security from technological, economic, social, and political perspectives.
6. Energy poverty and inequality, etc. (It seems that new trends and changes are on the way).

All these forces threaten the future of energy security, especially in regions where policymakers are unfamiliar with its concept, risks, and consequences (i.e., resource-rich economies). So it is time to act and create a shared vision. Why? To improve the quality of life, it is needed to think globally and investigate others' interests to design win-win international programs, then act locally and based on exclusive (dis)advantages.

About Iran's Historical Energy Development and Policies

In order to improve the energy sector in Iran, several energy laws and policies, the most important of which are the rules of 5-year economic and social development plans (six rounds), general energy policies, general policies of the resistance economy, energy consumption reform law, and subsidies orientation law, as well as Iran national energy strategy and Iranian oil and gas vision 2025, have been passed and formulated in the past three decades. These policies and laws mostly emphasized

Table 1 Energy security evaluation for Caspian Sea energy importer nations

	Resources and dependency		Intensity and sustainability		Cost and poverty		Total value		
Country	1991	2018	1991	2018	1991	2018	1991	2018	% of change
Azerbaijan	−1.2605	0.2458	0.7564	−0.1645	−2.0190	1.5665	−2.5232	1.6478	+%165
Iran	0.7790	3.7859	2.0920	0.4336	0.1536	1.2149	3.0248	5.4345	+%80
Kazakhstan	0.2930	1.3721	−1.3305	0.1697	2.4273	0.6682	1.3897	2.2101	+%60
Russia	3.8709	4.8491	−2.9096	−0.7593	2.3308	−0.9388	3.2921	3.1509	−%5
Turkmenistan	−0.6902	−2.3796	0.0647	0.2154	−2.2700	−1.1950	−2.8955	−3.3592	−%16
Uzbekistan	−2.9922	−3.2134	1.3270	0.1050	−0.6227	−1.3158	−2.2879	−4.4242	−%93

Modified based on Karatayev and Hall (2020)

decreasing energy intensity, developing renewable energy and increasing the share of renewable energy in Iran's energy mix, increasing energy exports and trades with neighboring and regional countries and strengthening the country's geopolitical role in the field of energy. Despite passing various policies and laws, there is no concrete medium and long-term energy plan in Iran to target reasonable objectives, especially regarding energy supply and demand. The energy sector in Iran is divided into two subsectors: (1) oil and gas, and (2) power. These two sectors are entirely governed by the Ministry of Petroleum (for the oil and gas industry) and the Ministry of Energy (for the power industry). As a result, the approach toward energy planning in Iran is sectoral (The establishment of the Supreme Energy Council, whose members are government ministers, failed to serve the goal of integrated and comprehensive energy planning in Iran). The lack of proper, comprehensive, and long-term energy planning has posed significant risks and vulnerabilities to Iran's energy security.

Ever-Increasing Energy Intensity Index in Iran

According to Fig. 3, Iran has a high energy intensity compared to many countries in the world and the world average. In addition, the energy intensity trend in Iran is upward, while most countries have already begun to reduce their energy intensity or at least maintain it at a fixed rate. Low energy efficiency throughout the energy value chain (from production to final consumer, especially in building and industry sectors) in Iran is the main reason for high energy intensity. The main contributing factors to low-energy efficiency in Iran are the diversity of decision-making centers in the country's energy sector (lack of integrated energy plan), lack of proper standards in the field of energy optimization and consumption, and lack of proper cooperation between energy consumers and producers.

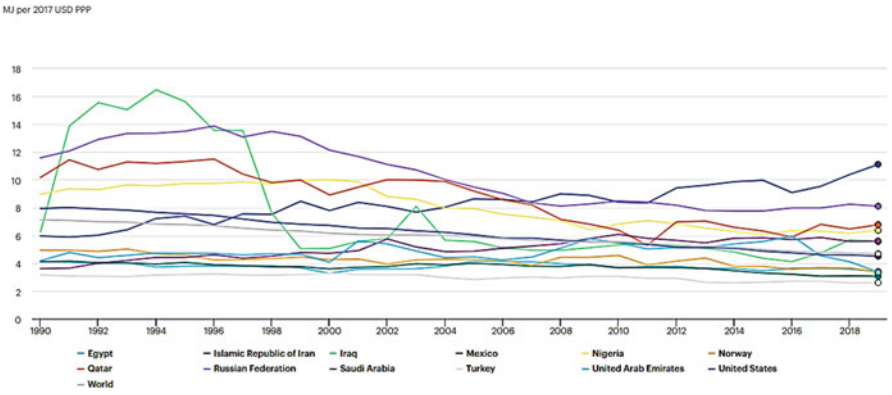

Fig. 3 Energy intensity of Iran and selected countries (International Energy Agency, 2022b)

Relying on One Source of Energy to Meet Iran's Energy Demand

After the discovery of the South Pars Natural gas field in Iran, energy policy-makers in Iran focused on meeting most of the domestic energy demand with natural gas to free more crude oil to export and increase Iran's oil revenue. This policy has been very persuasive, according to Fig. 4 the share of natural gas in Iran's energy consumption has reached almost 70% (since 80% of power in Iran is generated by natural gas-fired power plants), and currently natural gas is the single source of energy in various sectors especially residential, industry, and petrochemical in Iran. Lack of attention to the strategy of diversifying energy sources, which is one of the fundamentals of energy security, could put Iran's energy security at serious risk, especially in energy consumption peak seasons like summer and winter. In recent years, Iran has faced some challenges in meeting the demand for natural gas in Winter and electricity in summer, which once again highlights the need for developing other sources of energy in the country. The share of nonhydro renewable energy in Iran's energy supply and consumption is hardly 1% which indicates a lack of comprehensive energy planning in Iran. However, Iran plans to develop 10,000 MW renewable power plants by 2025 (Renewable Energy and Energy Efficiency Organization (SATBA), 2022).

Failing to Control CO2 and Air Pollutants Emission

CO2 and ambient pollutants (like CO, NOx, and SOx) emissions in Iran are on the rising trend. Power plants, residential, transportation, and industry sectors are the largest CO2 emitters in Iran, respectively, continuing urbanization, increasing migration toward metropolitans, growing the number of lower-than-standard vehicles (especially in the case of public transportation), failing to increase the thermal efficiency of vehicles, relatively small share of railway transportation in transferring commodities and passengers, and utilizing aging and nonstandard equipment, and

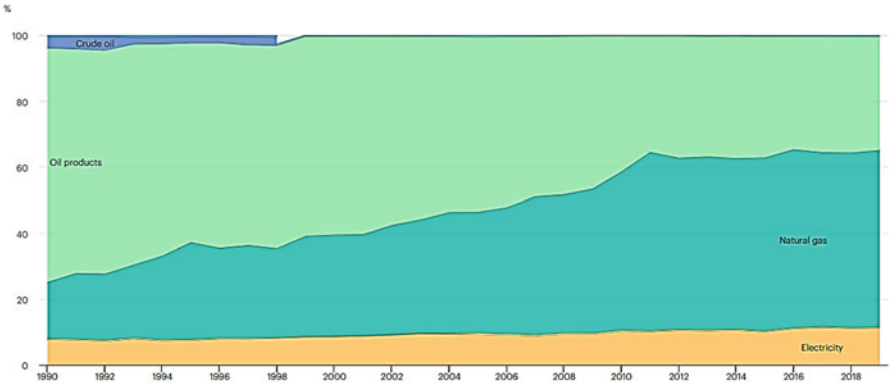

Fig. 4 Iran's energy consumption by source (International Energy Agency, 2022a)

vehicles are among the most contributing factors to Iran's rising CO2 and air-pollutant emissions trend.

Characteristics of Energy Security in a Resource-Rich Economy

To interpret the energy security from the side of resource-rich economies, the first step is asking meaningful questions about the concept of energy security with a systematic view to ensure investigation of different sides of the problem. The STEEP analysis is a known tool to evaluate external factors which can influence trends from a futuristic perspective (Akinyele et al., 2018). STEEP is named based on headwords for **S**ocial, **T**echnological, **E**conomic, **E**nvironmental, and **P**olitical. Here, the STEEP analysis framework has been modified since some characteristics are correlated significantly. For example, social and environmental characteristics are entangled since environmental concerns ignited social movements. Examining trends of the last 50 years shows that social demands for clean and safe energy sources are rising exponentially which reveals that the socio-environmental characteristics behave chaotically and need quick reactions. Socioeconomic characteristics are followed up by the public and NGOs. In an early conclusion, since in resource-rich nations energy sources are governed by the states, policymakers have a poor understanding of environmental risks and nongovernmental agents have no voice due to overregulations and extensive bureaucracy. On the other side, political and economic characteristics are correlated significantly, especially in a resource-rich economy where (mostly) economic growth is theorized and developed based on access to a natural competitive advantage, means cheap energy. In an energy exporter country, the most problematic challenge is deciding whether energy is a public good or a strategic commodity(?). This is the field of government and the business sector. As a result, a mixed category is developed named Econo-political characteristics which is mostly dominated by governmental agencies in resource-rich nations (such as Iran, Russia, etc.).

A third dimension plays a role but not to the strength of the previous two. Technological characteristic as an emerging dimension with new modern energy solutions and also challenges is an important diver for the energy security in the future. Referring to the energy market's structure agents in charge of technology development will be different.

The following sections are dedicated to discussing mentioned characteristics in detail, for the case of resource-rich economies, with facts and figures from Iran as a case study.

Socio-environmental Characteristics

As noted above, environmental concerns attracted attention in the last decades. International treaties such as Kyoto Protocol, Paris Agreement, the Glasgow Climate Pact (COP26), etc. were attempts to encourage states to control greenhouse gases

emissions, especially in terms of CO2 emission which is known as the prime suspect for the global warming (Florides & Christodoulides, 2009). In addition to environmental concerns, states are under public pressure. In the developed world, people ask for sustainable development and actions to protect nature. However, in the developing world, society demands a more affordable energy supply to meet the needs of the modern lifestyle. Its signs can be seen in the difference in the social activism of civil society in developed Western European countries compared to developing countries such as China, India, and Iran. Different needs and levels of quality of life cause different social attitudes and demands. In this chapter, I try to address the difference based on access to natural energy sources and how energy security translates into a resource-rich economy.

Moreover, as noted before, emission reduction and sustainable development of nations are new global targets that can limit economic growth in an energy resource-rich economy with a high competitive advantage in terms of cheap fuel. So, it is rational to conclude that *production* (especially in energy-intensive industries like the steel industry) in such economies receives higher priority than *service*. On average, production consumes more energy compared to service-based businesses. In addition, the lack of sensitivity to energy prices in resource-rich countries restricted energy efficiency programs which magnify energy consumption, and as a result, high emission rates are recorded. The high energy intensity rate implies the low energy efficiency of the economy proves this fact.

The Middle East and North Africa (MENA) countries with a critical role in oil and gas energy markets are good examples to examine energy security from the perspective of a resource-rich economy. Here, the case of Iran is discussed. However, I try to maintain the comprehensiveness and generalizability of the text.

For the socio-environmental factor, three characteristics are investigated. These three characteristics are presented in Fig. 5. Each characteristic is explained in detail in the following subsections.

Poverty and Inequity

Energy poverty is a problematic concern in all regions; however, its intensity fluctuates (Deller et al., 2021). The literature shows energy poverty is challenged from the household side, rather than business and industrial sectors. Like energy security, energy poverty has no agreed definition, which means we cannot evaluate the degree of energy poverty or inequality accurately and validated. In addition, different characteristics of users (social side) and vague biases both from decision-makers (political side) and researchers (academic side) made energy poverty a vague and personalized concept. But there is a consensus: Energy poverty and inequality are global challenges. Although access to energy is not a national challenge in resource-rich economies, it is estimated that in the future it will arise as an emerging challenge, even in resource-rich regions. Why? Population growth and the tendency to accelerate GDP value, mostly based on access to cheap energy sources as a competitive advantage, will keep energy demand trends above the world average. In the case of Iran, the domestic gasification policy, which was aimed to increase the country's oil export potential and fight against energy poverty via providing natural

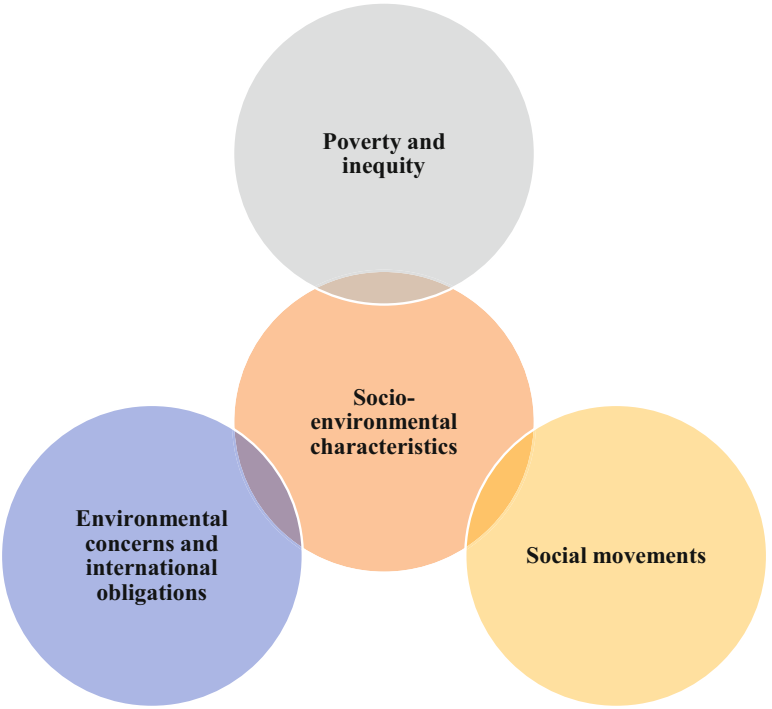

Fig. 5 Characteristics of the socio-environmental factors. (By authors)

gas for households all around the country, caused a national energy-related crisis, the energy supply, and demand imbalance. Reduction of extraction rate from the South Pars gas field (Heidari et al., 2022) and international sanctions caused upstream technology backlog due to limited funding of opportunities initialized, a neglected trend, overtaking domestic demand from natural gas production. Figure 6 shows the national supply and demand for natural gas from 1970 to 2020.

Moreover, international environmental obligations and estimated future emission taxes threaten future energy security in Iran, especially since these forces will drive the spread of energy poverty (especially based on the current national energy supply basket which supplies about 70% of electricity via gas-based power plants). To address environmental concerns, it is crucial to consider both energy exporters and importers' interests and needs.

Social Movements

Social movements are organized programs in support of a social goal. The significance of people's influence on energy transition has been debated and proved by previous studies (Ryghaug et al., 2018). Most of such studies emphasized climate change and social movements to preserve nature. For example, Campos and Marín-González studied the relationship between social movements and energy transition

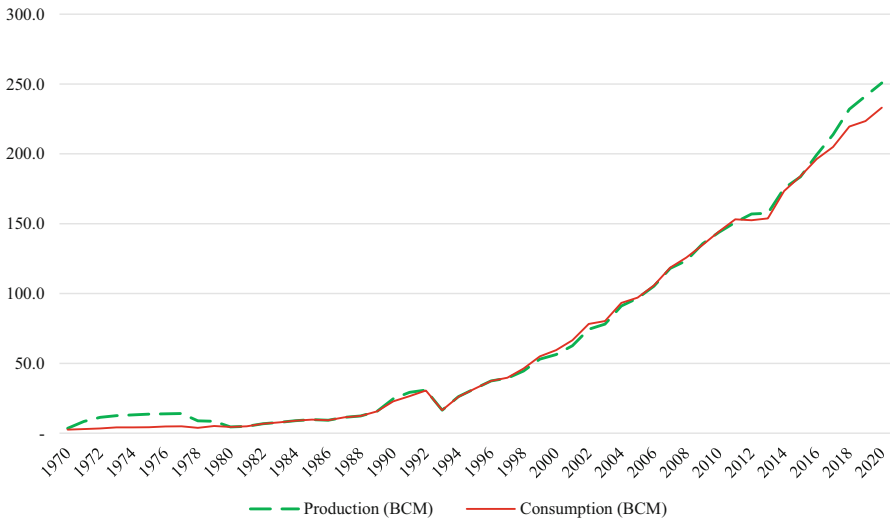

Fig. 6 Iran's natural gas supply and domestic demand. (Source: BP statistics)

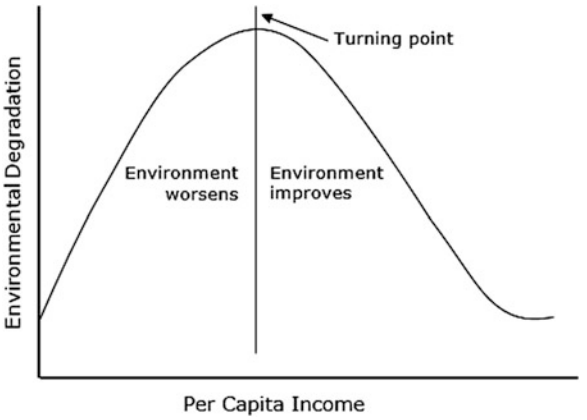

Fig. 7 Environmental Kuznets Curve. (Modified based on Waslekar (2014))

in Europe (Campos & Marín-González, 2020). The authors draw on a review of Social Movements Theory and apply thematic analysis to characterize 46 prosumer initiatives in Europe. Results showed that end-user behavior is converging toward a transformative social movement (Campos & Marín-González, 2020). Similar results were reported by other researchers for different regions (for example, examine (Ghaboulian Zare et al., 2021) Australian residential behavior for the case of solar water heater adoption).

However, the literature review shows that a weak signal is neglected. As the environmental Kuznets curve (EKC) (Dinda, 2004) suggested, economic development will reverse the man-environment relationship. See Fig. 7.

The relationship will redefine after a certain level of economic growth, and the society begins to improve its interactions with nature. Here, we propose that social movements will support environmental concerns when a certain economic level was met, otherwise society expected a sustainable energy supply with a high priority on fighting against poor access to energy (i.e., energy poverty). So existing literature ignored the social demand for affordable energy in resource-rich economies where environmental international obligations dictate limited use of fossil fuels that can threaten access to affordable energy sources in fossil fuel exporters, such as Iran. Based on EKC, civil societies are demanding conflicting national policies referring to economic growth, access to energy sources, social values, and energy-governing paradigm, especially in resource-rich economies such as Iran where energy is assumed as a public good.

Environmental Concerns and International Obligations

Environmental problems, alongside energy security, have become one of the most important elements of the energy policy-making process in different countries around the globe (Wang et al., 2018) as ensuring sufficient energy supply to meet growing energy demand, mostly from developing countries, while limiting greenhouse gas emissions is one the most challenging task of policymakers (IEA, 2007). Despite environmental concerns being recently introduced as energy policy challenges, energy and environmental problems are closely interlinked (Sovacool, 2014) and almost all the operations through the current energy supply value chain from energy production to energy distribution cannot be done without substantial environmental effect (Dincer, 1998). Two of the most sensible implication of energy-induced environmental problems are climate change and pollution (including air, water, and land pollution). Such threats caused a considerable amount of capital to support low-carbon technologies such as solar photovoltaic and wind turbines. According to the latest IEA data, investment in renewable power has been continually rising, and in 2021, the amount of capital invested in renewables is the same as oil and gas upstream (IEA, 2021). These turns of events that would shift the global energy systems toward low-carbon energy sources and technologies would have considerable implications for the energy security of energy exporter and importer countries. In energy-producing countries, most of which are categorized as developing economies, there could be some energy subsidy reforms in order to save more energy for export at a time when still fossil fuels are in strong demand. On the other hand, in energy-consuming countries, most of which are categorized as developed economies, trying to reduce fossil fuels could translate into higher volatility in energy prices in the short term. Since most of the energy security strategies that were adopted by policy-makers are only based on providing sufficient, reliable, and affordable energy and do not observe new environmental problems and fast development of low-carbon technologies, it is necessary to evaluate the impact of development in these areas on energy security of different countries (Proskuryakova, 2018).

In the next three subsections (*a*, *b,* and *c*), we try to elaborate on the implications of two main drivers of environmental concerns, i.e., climate change and air pollution,

and the solution to address these concerns, i.e., low-carbon technologies, on the energy security of different countries.

(a) *Climate Change*

A safe environment is vital for human activities, and it is being put at risk by global warming, one of the most demanding challenges of humanity (Asif, 2021). Natural disasters in the form of extreme climatic events such as floods, wildfire, hurricanes, droughts, etc. doubled between 1980 and 2004 and are about double again by 2040 (Hammond, 2019). As a result, climate change is an existential threat to the energy security of a country in many ways, most important of which are disrupting the process of production, transmission, and distribution of energy and fuels and bringing on environmental refugees, that could limit the availability of energy for a host nation (Sovacool, 2014). Figure 8 shows the historical and future trend of carbon dioxide emissions, which is considered the most important greenhouse gas in terms of impact on global warming (Brander & Davis, 2012).

As shown in Fig. 8, carbon dioxide (CO_2) emissions have been consistently rising in the last three decades, and this trend would not alter significantly during the next three decades if governments do not fundamentally change their current policies (Business-as-usual green line). Reversing the rising trend of CO_2 emissions requires a significant reduction in fossil fuels, especially coal and petroleum. While most of the developed countries are already on the path to reducing coal share in the energy consumption mix, decreasing oil consumption could pose a substantial risk to the economic growth of oil-producing countries like the countries of the MENA region.

At the national level, most oil-producing countries are heavily dependent on crude oil and natural gas to meet their energy demand, and their need for energy

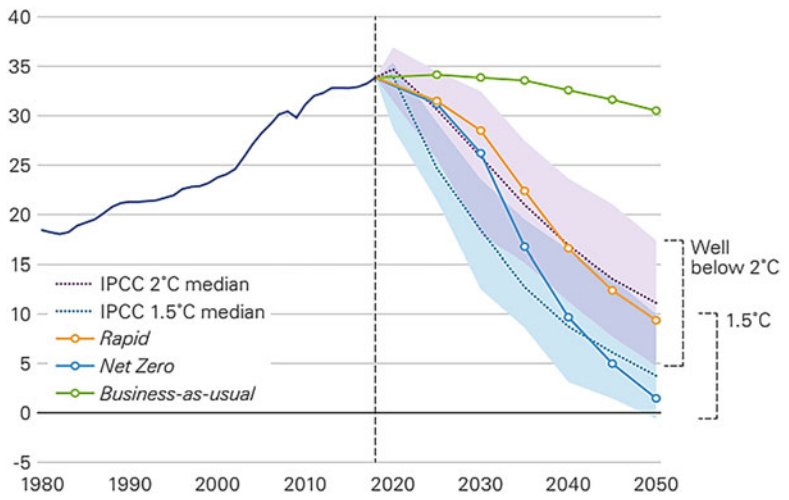

Fig. 8 Historical and future trend of CO_2 emissions based on different scenarios (BP, 2020)

would continue to grow as both population and economic growth are projected to keep up in the future. This means that they would need more energy supply, mostly from fossil fuels, which could heighten climate change.

At the international level, the rising possibility of stranded resources as a result of the required reduction in oil demand to limit global warming could create intense competition between producing countries to monetize as much as barrels of oil as they can.

Therefore, such countries not only should diversify their energy supply resources (or take serious demand-side measures) to mitigate climate change impacts and release more fossil fuel energy to export but also should diversify their economy away from oil revenues in order to maintain their growth in the postoil era (such action are already taken by some countries in Gulf Cooperation Council (Sever et al., 2019)).

(b) *Pollution*

Apart from global warming, pollution, especially in the form of air pollution, has attracted considerable attention as an energy security concern. Two types of air pollution are responsible for the death of almost nine million people around the world (Lelieveld et al., 2019): outdoor air pollution and indoor air pollution resulting from burning traditional fuel for cocking (Jacobson, 2009). Air pollution also causes a vast range of diseases from cardiovascular to respiratory (Landrigan et al., 2018) and school-day and work-day loss, which could have adverse social and economic effects. Fossil fuel use in the transportation and power generation sectors and energy-intensive industries is the main driver of air pollution, mostly in metropolitans (Brauer et al., 2016). Figure 9 shows the number of deaths from fossil-fuel-induced air pollution in different countries.

As shown in Fig. 9, fossil fuels were responsible for more than 40% of air pollution deaths in 2015. And the most industrialized regions of the world, meaning East Asia, Europe, and North America, are the three most affected regions. Resource-rich countries, meaning west Asian and African countries, are less affected. However, as urbanization and industrialization are projected to continue in these regions, their susceptibility to air pollution would be much higher if they plan to meet their growing energy demand with fossil fuels. On the other hand, shifting away from fossil fuels, which are their competitive advantage, could have deterring effects on their economic effects and would risk their energy supply security. As a result, it seems that the governments of such countries face a dilemma of improving the air quality of ensuring energy supply security. In such circumstances, there is a range of actions that could hold the balance between improving air quality and maintaining energy security including but not limited to leveling up energy efficiency and energy conservation, shifting the economy from energy-intensive industries to less energy-consuming services, using carbon capture technologies and gradually diversifying the energy supply mix toward low carbon energy sources (Bollen, 2008).

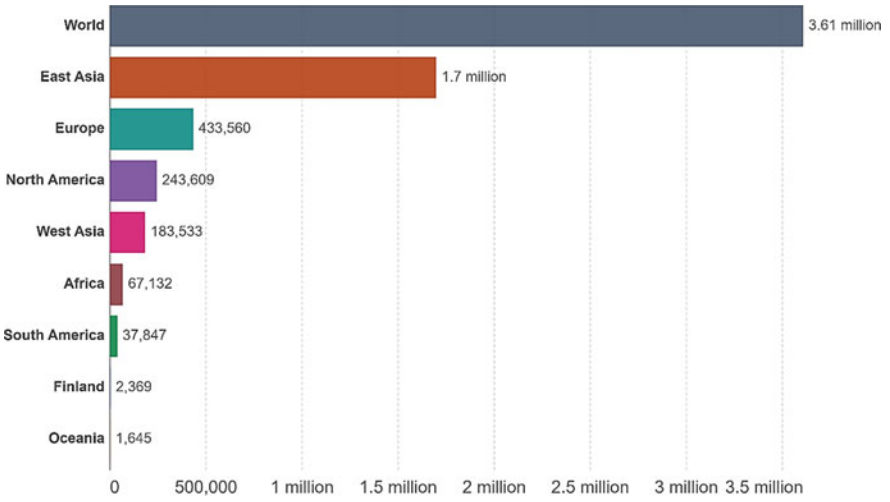

Fig. 9 Air pollution death from fossil fuels 2015 (Lelieveld et al., 2019)

(c) *Emerging Technologies (With Unknown Consequences)*

Emerging technologies' risks and rewards should be closely evaluated as the trans-border feature of technologies means they could threaten the security of a nation if they are not properly understood (Heinonen et al., 2017). Since energy plays a critical role in social, political, and economic developments, new technologies in the field of energy should be considered in energy security concern. As global energy systems are experiencing a gradual shift from high-carbon to low-carbon energy sources and technologies, new risks and vulnerabilities will introduce to energy systems (Johansson, 2013).

According to Fig. 10, biofuels are the most consumed renewable energy source in the world. However, the share and amount of wind and solar energy sources would increase in different scenarios (Heidari et al., 2022).

Such an energy transition era could result in political instability in fossil fuel-producing nations and threaten their energy security as their revenues from energy export are predicted to decrease. Because of their rentier economy, the accelerating development of low-carbon technologies and energy sources could result in national and regional unrest. If environmental-friendly energy systems that could produce more amount of energy at lower prices are realized, these consequences could be further heightened by disruptive technologies such as big data, artificial intelligence, automatization, distributed ledger, Internet of everything, smart cities, and robotization, and this kind of situation could increase volatility and uncertainty (Heinonen et al., 2017; Umbach, 2018).

On the other hand, current widespread renewable energy technologies, i.e., wind and solar, are vastly interconnected to weather and climate conditions, and it seems that renewables are more susceptible to climate change than fossil fuels (Schaeffer

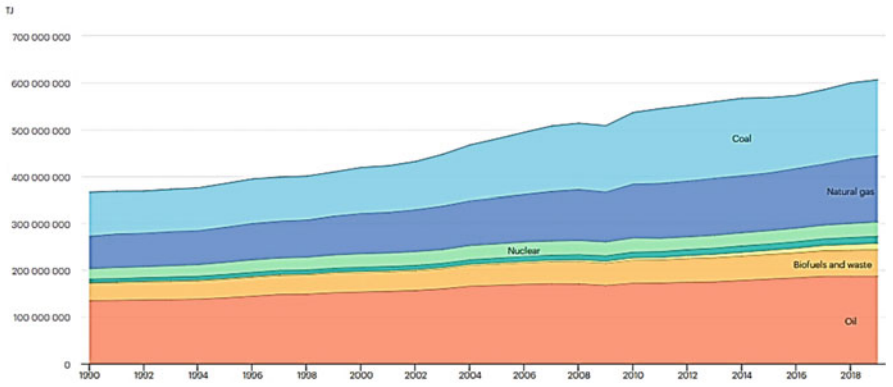

Fig. 10 World total energy supply by source 1990–2019 (IEA)

et al., 2012). Also, the alternative nature of generating electricity from renewables means that a smart grid should be deployed which poses substantial security risks to energy systems, the most important of which is cyberattacks (Amin, 2012). As the share of renewable energies increases in the world energy supply, the risk of oil supply-side shocks will decrease at the expense of increasing the risk of minerals' supply-side shocks, as the vast amount of proved reserves of required metals for manufacturing renewable technologies is highly concentrated in few countries **(**Ref Dominish et al., 2019).

Before radically shifting the energy supply mix, oil- and gas-producing countries should be fully aware of numerous risks and vulnerabilities that their economies and energy systems would face and properly plan to address them.

Econo-political Characteristics

Energy has always been the backbone of every economic development and economic growth, especially since the industrial revolution. In fact, since 1850, every economic development from the industrialization of western economies to the rise of China as an economic power translated into higher energy consumption, mostly in form of fossil fuels (Fig. 11). The increasing trend would continue in the next two or three decades as economic growth from developing countries (East countries) would go on. Therefore, energy security would continue to be a challenge for policymakers, because of its highly positive correlation with economic growth.

On the other hand, energy also has served as a political tool both at the national and international levels, especially for resource-rich countries. Domestically, politicians in resource-rich countries are trying not only to ensure the availability of sufficient energy for everyone at an affordable price (energy as a public good or a commodity), but also they have to utilize their relatively low-cost energy sources as a

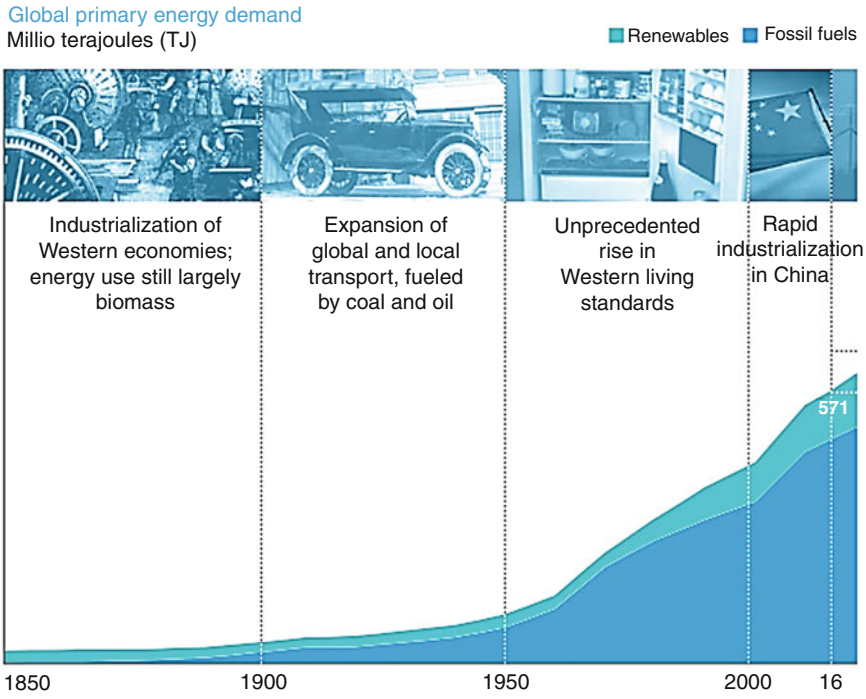

Fig. 11 Global energy consumption (McKinsey & Company, 2019)

competitive advantage to support their economic growth, a dilemma that is difficult to overcome.

At an international level, energy often has been used as foreign policy leverage to pressure countries. In the 1970s, this tool was mostly in favor of energy exporter countries by refusing to sell sufficient amounts of fossil fuels to other countries, like the Arab oil embargo in 1973 or the high dependence of European countries on Russia for energy supply, mostly because of the belief of "fossil fuel scarcity" was the dominant philosophy of the oil markets. But with rapid technological advancement in the exploration and development of oil and natural gas fields and the advent of deep and very deep-water oil and gas and shale oil and shale gas, the dominant paradigm of energy markets began to shift from age of scarcity to the age of abundance. The consequences were further intensified by the climate-change mitigation action targeting the reduction of fossil fuel consumption. The new paradigm of the oil market has allowed energy-consuming countries to also use energy as a foreign policy tool by impeding oil-producing countries from selling oil through primary and secondary sanctions, similar to what has been done to Iran and Venezuela in recent years.

In the next four subsections, we try to evaluate the effect of the aforementioned characteristics on different aspects of energy security, meaning energy price, affordability, energy as an economic driver, and energy as a public good.

Energy Price

Energy price is one of the crucial elements of energy security, and high volatility in energy prices could have severe effects on the future of the economy as it has a considerable share in family expenditure, and can raise the competitiveness of an economy and affect the energy consumption (IEA, 2022). As energy markets, especially oil markets, are relatively concentrated markets, with OPEC (Organization of petroleum-exporting countries) members holding almost 80% of global proven oil reserves and producing more than 40% of total world oil barrels (OPEC, 2021), energy prices are not determined only by the market mechanism and political factors like sanctions, the level of crude oil stocks, surplus crude oil production capacity, market liquidity, etc. can significantly fluctuate global energy prices (Mróz, 2022). Therefore, energy prices are relatively volatile. This volatility is being further intensified by energy transition measures and black swans like global pandemics which create short period and high volatile price cycles (like what happened in 2020 as oil markets and energy companies recorded their worst performance but in 2021 and early 2022 recorded their best performance in almost a decade).

This kind of volatility affects energy importer economies by varying their expenses and exporter economies by varying their revenues. Either way, volatile prices are considered an energy security issue and must be addressed by various mechanisms like the construction of strategic petroleum reserves or curbing/increasing production.

However, volatile energy prices in the global market have a modest effect on the domestic energy price of energy exporter countries as their energy markets are heavily regulated and subsidized. This subsidized regime could be a double edge sword. In one way, it could protect consumer expenditure from global volatility and increase the competitive advantage of domestic energy-intensive industries. In another way, it might promote uncontrolled energy consumption and not provide enough incentive to launch energy efficiency projects that eventually could result in a supply/demand gap and lack of financial resources, and subsequent fiscal deficit and public debts (Amer et al., 2016). In addition, energy subsidies have contributed to increased inequality in developing economies as high-income households usually benefit way more than low-income ones from fuel subsidies, and it limits the ability of a government to allocate sufficient financial resources to other areas for public interest like education and healthcare, etc. (Couharde & Mouhoud, 2020). Therefore, energy subsidy reform seems to be critical for resource-rich countries, but it should be implemented with complementary policies and in a way that minimizes its impact on poor and vulnerable households.

Affordability

Affordability could be considered the most important aspect of energy security as the ability to access affordable energy is vital to every aspect of human life: work, education, heating/cooling, cooking, etc. (Brown et al., 2020). Higher energy prices that limit the ability of a household to afford its energy bills could finally lead to a

situation called "fuel poverty" that was first found in developed countries like the UK, Europe, and the USA as a result of energy market liberalization (Chester, 2014). Since then, mitigating its consequences is a political priority in developed countries, but in developing ones, especially fossil fuel-rich countries, it has received less attention (Belaïd, 2022). Affordability is often measured by the energy burden indicator which is the total cost of utility bills for energy services of a household. Different elements contribute to the high energy burden, most significant of which are energy prices, housing energy performance, household fiscal situation, and socioeconomic condition of a given country. Although in most oil-rich countries like Iran energy bills are responsible for less than 6% of total household expenditure, which is a benchmark for unaffordable energy (Colton, 2011), local energy prices are much less than global ones. This kind of situation is a result of low standards of income in such countries which force governments to heavily subsidize fuel markets to prevent fuel poverty in their countries.

However, in such countries because of inappropriate subsidy regime, the energy burden for low-income households is way more than the energy burden for wealthier families and affectively high-income households receive more energy subsidies by consuming more energy; therefore, there is no incentive to conduct energy efficiency projects, even for wealthy families who can afford such investments. Subsidy regimes in oil-rich countries must be reformed in a way that increases the energy burden for high-income households (to provide sufficient incentive for energy efficiency) and decreases the shared energy in the total spending of low-income households. This kind of subsidy reform could provide more financial resources to the government domestically and internationally that could be allocated to the empowerment of impoverished households and maintain the affordability of energy for more needed people. Gradually by increasing the economic growth, living and income standards, energy subsidies could be considerably reduced without having serious consequences like fuel poverty.

Energy As an Economic Driver

Energy is a key element of economic development and is considered a foundation for economic growth and rising living standards; therefore, ensuring energy security is one of the most important pillars of every economic development plan (Le & Nguyen, 2019). Increased instability and volatility in global and regional energy markets have severe consequences for the economic growth of not only energy importer companies but also energy exporters. On the other hand, increasing energy consumption leads to more carbon emission that has adverse effects on human health and living. In fact, energy consumption to support economic development is responsible for about 36 billion tons of carbon emission per year (Fu et al., 2021). As a result, securing a sufficient amount of energy without a significant rise in carbon emission is a critical challenge to every government. In this context, the most favorable solution among policymakers is energy efficiency. There have been numerous studies in the literature about the economic benefits of energy efficiency from reducing dependency on energy imports to reducing energy intensity and improving energy security (Mahmood & Ayaz, 2018). This solution is particularly effective in oil-rich countries where because of the abundance of fossil fuels energy-

intensive industries like cement, steel, refinery, and petrochemical are the core of the industry sector in these countries and there is a considerable potential to save energy in these industries which can be realized by state-of-the-art technologies.

Many resource-rich countries also look to renewable and to some degree nuclear energy to support their economic growth. It is argued that although diversifying energy sources could improve energy security since the required technology for renewable and nuclear energy are highly monopolized, reliance on such energy sources to meet the energy demand required for economic development could further risk energy security and deprive different sectors of more available, accessible, and affordable energy sources. Therefore, governments in such countries should maintain the balance between local and imported energy sources and try to localize imported energy technologies to further improve their energy security and economic growth while limiting their carbon emissions.

Apart from technological progress, a structural shift from industry-intensive to more service-based economies might significantly contribute to maintaining economic growth and limiting carbon emissions simultaneously; however, developing service sectors would also require energy-intensive infrastructures that may reduce their impact (Stern, 2011). Therefore, energy efficiency technologies that enable manufacturing industries to produce more with less energy and in the next step recycling technologies that enable industries to produce more with less raw materials would be the key to maintaining economic growth, improving energy security, and limiting carbon emissions.

Energy As a Public Good in Resource-Rich Economies

Although natural resources, and their following economic rents, could be very beneficial for the development of a country, if properly managed (Barma et al., 2012), resource-rich countries tend to use their natural resources inefficiently and detrimentally which is referred to as "natural resource curse" (Abreu et al., 2022). In most natural resource abundance countries, the government resource and spending budgets are usually highly correlated with commodity prices; therefore, they tend to follow short-sighted policies that eventually would result in stagnation and inefficient economic situation. In such circumstances where governments are unable to alleviate the economic restraints of their nation, they prioritize meeting the ever-increasing energy demand of households at the expense of the shutdown of industries. Therefore, energy is seen as a public good in most resource-rich countries like Iran. But if the correlation between government spending and revenues from energy exports is eliminated, the natural resource curse would turn into a natural resource holy grail. Something that happened in Norway by establishing an oil fund to eliminate the aforementioned correlation. These types of funds to manage surplus oil revenues have been established in other energy-exporter countries like Venezuela, Iran, etc., but they are not successful as the Norwegian version mostly because of poor governance.

Looking at energy as a public good in most resource-rich countries has led to the government's inability to control energy consumption and improper energy subsidy regime which are increasing risks of energy insecurity. On the other hand, more

economic challenges would result in more energy security risks. One of the key ways to break this vicious circle is for resource-rich countries to peruse long-term development policies rather than short-time populist ones that most often than not would privilege elites rather than the public. These policies included but were not limited to the following: gradually diversifying the economy in favor of technological progress and reducing the share of oil revenues in public spending, reforming subsidy regimes, and providing investment in energy efficiency projects.

Technological Characteristics

Technological progress in the field of energy could affect resource-abundant countries in two paradoxical ways. In one way, emerging new technologies enable humanity to use alternative energy sources like wind, solar, geothermal, and even electromagnetic and also to use current energy sources in a more efficient way that would ultimately lead to adverse economic consequences due to reducing global fossil fuel consumption. But at the same time, technological advancement in the field of exploration and development of hydrocarbon fields like seismic studies, hydraulic pulsing, nano-engineered materials, and powerful analytical tools will result in more hydrocarbon production in a more efficient way that would result in more economic benefits for resource-rich countries. Such technologies also turn some countries that were traditionally energy importers into energy exporters and disrupt the energy markets (Franki & Višković, 2015). It seems that energy-consuming countries are advocating alternative energy source technologies and oil exporter countries continue to develop technologies to produce more efficiently (Kim, 2014). Governments' interventions in energy markets and their energy policies are the key drivers of the development of such technologies. As a result, technology is helping countries and nations to access more energy and improve their energy security in terms of availability.

However, some technologies have been developing outside of the energy sector but are of the potential to disrupt global energy systems. Aside from decarbonization which has been assessed in previous sections, digitalization and decentralization are the other technological factors that could have incredible implications for energy markets (Umbach, 2018). These technologies are transforming the traditional way of running businesses in the energy sector and changing consumption patterns, for example, by managing building energy consumption utilities energy allocation through cutting-edge software. These transitions would introduce new actors to the global energy systems and bring new vulnerabilities and risks to different aspects of energy security including availability, accessibility, and sustainability that should be evaluated closely to prevent future shocks. The next two subsections will investigate the effect of digitalization and modern markets on energy security.

Digitalization

Digitalization and electrification of transport and heating sectors and the imminent fourth industrial revolution, which will be built on robotics and artificial intelligence,

would lead to higher energy demand, especially in the form of electricity, which highlighted the importance of safe and secured energy infrastructure in the future.

The rapid advancement of the Internet and transporting a huge amount of data in the global energy systems would increase the risk of cyberattacks on energy infrastructures in the case of geopolitical tension. There are three implications for the digitalization of the energy sector as follows (Umbach, 2018):

1. Ever-increasing of electricity demand: Though digitalization might offer opportunities to promote energy efficiency and energy saving, new technologies have been energy-consuming and would result in increased electricity demand.
2. With the rapid incorporation of digital technologies into energy systems and increasing adoption of smart grids and the Internet of Things (IoT), the risk of cyberattacks interrupting energy supply would amplify.
3. Digitalization including artificial intelligence (AI) systems and robotics alongside the increasing adoption of renewable energy, which is usually considered an Indigenous and local energy source that could ease the dependence on imported energy sources, might lead to change in the geopolitics of energy as the production of key metals to manufacture renewable installations are concentrated in a few countries.

Economic superpowers like China that are technological pioneers and dominate the production of key metals and manufacturing of renewable installation could turn into new monopolies in the energy sectors. Therefore, in the digitalized world, metal and mineral resource security would be an important aspect of energy security. In their strategies to improve energy security, governments, particularly fossil fuel-rich ones that would be more dependent on foreign technologies and nonenergy resources, should address such future challenges.

Modern Open Markets

Energy demand growing at a fast pace, especially in the type of electricity. As a result energy policy, planning, management, and monitoring became challenging concerns. Traditionally, energy sectors are managed via a fixed hierarchy with limited suppliers and multiple users (Pepermans, 2019). But, the classic style of energy management is no longer in fashion due to (1) diversified energy sources, such as modern renewable ones, (2) rising demands for electricity, (3) nations' insecurity challenges (Hafezi & Alipour, 2021), and (4) fighting against energy poverty. Also, regional interconnected power grids (for example, the European power grid (Rosas-Casals et al., 2007)) and smart grids are in vogue. These shifts in traditional markets need paradigm shifts emphasizing diversification both in terms of sources and stakeholders, and tools to face more complex market rules.

Technological advancement would often lead to structural market shifts. In the case of electricity markets where most of the technological developments are happening like solar PVs, wind turbines, and smart grids, the role of consumers is transforming from passive actors, who just receive power to more active ones, who also feed the network. In fact, traditional one-way electricity markets are turning into

modern two-way markets where houses and buildings could also sell their surplus power generated by renewables to other consumers (Savolainen & Svento, 2012). Also, the rapid progress of information and communication technologies alongside emerging technologies like distributed ledger has resulted in a concept called sharing economy (SE). In general, sharing economy is a peer-to-peer act of obtaining, giving, and sharing goods and services through online services (Hamari et al., 2016). Such structural shift is already happening in the travel accommodation market and sooner or later would be adopted in the energy markets as the energy systems are shifting from centralized energy production to more decentralized ones. Such developments would have huge impacts on consumption patterns and market behaviors and consequently on national energy security that must be fully understood and prepared to address its risks and vulnerabilities.

As noted before, smart grids are changing how policymakers monitor and control electricity distribution networks. They are changing the future electricity markets with entanglement in communication technology, interconnected power systems, advanced control technology, and smart metering. Moreover, smart grids enable energy systems to transmit energy and information on both supplier and user sides (Judge et al., 2022).

Meanwhile, blockchain technology emerged as a modern age game changer, especially in the case of markets with large financial transactions. Introducing blockchain to the smart grid has valuable benefits like minimizing data management, regulatory costs, technical issues, transaction fees, and price adjustment issues. Blockchain also increases the transparency between participants, data security, and privacy and helps to reduce transmission and distribution loss and better supply and demand management of the grid (Aklilu & Ding, 2021).

A more comprehensive model to study the energy security concept has been proposed and illustrated in this chapter, focused on resource-rich economies. Next, policies to improve energy security are recommended and discussed to highlight how the concept will be different from energy exporters' perspective.

Conclusion and Policy Recommendation

This section is dedicated to problems and examines strategies tailored for importers and exporter countries, emphasizing the role of governments to improve energy security levels. As noted, in most cases energy security has been examined from the perspective of energy importers, due to the 1970s energy crisis. However, this chapter noted that since new energy-related issues are emerging and the complexity level is increasing, resource-rich economies are also facing energy security challenges. In other words, the concept of energy security is evolving into a more comprehensive mode.

Classically, to level up the energy security at the demand side (i.e., energy importers), nations are recommended to adapt their strategies in line with (Hafezi & Alipour, 2021):

1. Invest outside the region to initiate joint ventures with oil and gas producers.
2. Improve the efficiency of domestic energy systems both in terms of distribution systems and technologies, and consumption patterns, to support energy sufficiency at a lower cost and energy import rate.
3. Establish and promote regional energy futures via a liberalized market strategy, where private sectors serve in a competitive environment to improve national energy security levels.
4. Finally, as a public service policy, governments can develop strategic energy carrier stocks (especially oil stocks) to prevent and adjust supply disruptions. Japan, South Korea, Australia, New Zealand, Taiwan, Singapore, and China, as energy importers, develop and maintain mandatory stocks of oil.

In contrast to energy importing countries, resource-rich economies are facing energy security from a different viewpoint. As noted by Hafezi and Alipour in such cases, availability of affordable energy sources threatened energy security in the following terms (Hafezi & Alipour, 2021):

1. Diversification: since main consumers (household, industries, and business sectors) economically prefer to use cheap and accessible domestic energy sources. Also, it can weaken the national passive defense level. Note that in most energy supplier countries, energy is categorized under public goods and governments must necessarily provide it.
2. Efficiency: Due to the availability of affordable energy sources, end-users and even energy service providers are not attracted to improve efficiency indexes as the difference between an optimized system and the existing one is not much, especially in terms of economic stimuli.
3. Environmental: As most known energy exporters are playing supplier roles in fossil fuel markets, extensive domestic dependency on such fuels threatened environmental quality (statistics show resource extraction is responsible for half world's carbon emissions) and such energy sources make more pollution rather than modern types of energy sources.
4. Economic dependency: Economies in energy-related regions are strongly tied to fossil fuel sales; as a result, a limited market share equals an adjusted GDP level and tends to develop domestic energy-intensive industries (to burn and process domestic cheap energy resources) which menaces sustainable development.

To deal with such challenges, we need to reorganize international energy markets and design win-win strategies, otherwise, it seems that the supply (resource-rich economies) and demand (energy importer regions) sides will play with different game rules which will cause the energy-related crisis, price fluctuations, environmental disasters, and even social challenges due to increasing need for affordable energy sources.

Assessment of energy security issues needs debating on concepts and concerns which help us to measure energy insecurity. A new emerging paradigm introduces new literature in the last decade defined as "energy insecurity" which emphasizes

undefined/covered threats and weak signals (Gheorghe & Muresan, 2011). These not well-studied threats will shape future decision-making principles in the case of energy. This shift is set to be the subject of policy circles in the near future. Dealing with a conflicting objective to expand energy access, while simultaneously controlling environmental impacts, due to energy use, is challenging for energy security.

There is no single prescription to improve energy security, but it would be helpful to analyze the case of Iran. Iran's challenges are mentioned in the text, so here a shortlist is provided as a policy recommendation for the Iranian government to improve energy security levels while managing threats on a short-to-medium-run horizon. Policies are proposed as follows:

1. Reforming domestic residential energy supply model: Currently, Iran supplies about 70% of domestic power needs based on gas-powered plants and almost all households have access to natural gas via national gas pipelines. It seems that Iran needs to redesign residential energy consumption based on electricity, rather than providing fuel (natural gas) and electricity simultaneously.
2. Upgrading power grids: Iran needs to upgrade power grids both in soft (regulation and management) and hard (hardware and physical facilities) terms. Currently, Iran's power grid is outdated. Moreover, it is centralized. A more flexible network with updated facilities is needed. In addition, the governance structure should be revised to adjust the state's role as a regulator and facilitator, instead of being a contractor.
3. Change the way policymakers use energy: The old fashion paradigm, energy as a public good (i.e., energy as a fuel), should be replaced by a new paradigm that is focused on the utilization of energy as an economic driver to control energy intensity levels. Now Iran's energy intensity level is significantly higher than the average global energy intensity level. It reveals that national energy consumption does not effectively push the economy.
4. Invest in upstream to improve extraction rate for both oil and natural gas fields.
5. Promote knowledge-based environmental solutions such as carbon capture, pollution monitoring, control systems, etc.
6. Diversification of domestic energy supply based on neglected national resources: Iran has significant renewable power generation potentials based on solar and wind powers, which have been ignored due to access to cheap oil and natural gas resources.
7. Developing a liberalized market (i.e., deregulation) can facilitate the change since in most energy exporter countries domestic energy markets are managed, controlled, and monitored by governments that slow down the transition to a more sustainable and secure energy system.

These are some ideas to improve Iran's energy security index. As a resource-rich economy, most problematic challenges rise from the economic side, where fossil fuel-based developments significantly are more feasible than modern energy sources. Although Iran experienced about two decades of international sanctions, the idea of shifting the energy governance paradigm is valid for other resource-rich

economies. This means considering energy resources as an economic competitive advantage as an input to a value-based system, instead of burning fossil fuels. Moreover, the energy security concept should be redefined comprehensively based on both energy importers and exporters' interests and concerns.

It seems that energy security will be an open question that needs active cooperation from both supply and demand sides. However, it is critical to remember that black swans (especially technological wild cards) can initialize radical changes. So it is vital to project multiple futures instead of developing a single one based on historical trends and experiences. For example, COVID-19 influenced short-term demand for oil which caused dramatic oil price falls (Algamdi et al., 2021), and the impact of high-temperature superconductors on energy demand (Kalsi, 2011), the occurrence of solar storms and how they can disturb energy systems (Belakhovsky et al., 2018), etc., can play as wild cards which influence energy security severely.

Cross-References

- ▶ Effective Factors and Policies in Electrical Energy Security
- ▶ Energy Convergence and Regional Energy Security: Policy Implications
- ▶ Energy Policies for Sustainable Development
- ▶ Policies to Alleviate Energy Poverty: From Fundamental Conceptions to a Practical Framework in the New Era

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