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Green-Growth Strategy in Iran: What Role Energy Mix & Transportation Sectors Can Play?

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이 논문은 공학 박사 학위논문으로 제출함

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바하레의 박사학위 논문을 인준함

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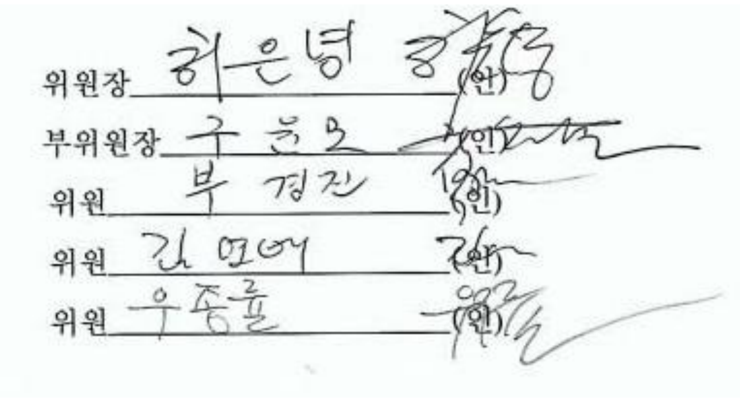

Abstract

This study aimed to design and structure the green-growth strategy for Iran regarding its energy-intensive sectors, namely the power and transportation sectors. Three essays were conducted to achieve this objective. By using the autoregressive distributed lag model and the error-correction model (ECM), the first essay investigated the short- and long-term environmental impacts of the energy mix in the transportation sector. The results confirm the negative and positive impacts of renewable electricity and economic growth on environmental degradation in both the short- and long-term. According to the results of the ECM-Granger causality test, economic growth and number of vehicles are drivers of CO_2 emissions in the long-term. The positive impact of vehicles on economic growth and CO_2 emissions suggests that boosting economic growth while simultaneously reducing the environmental side-effects caused by road traffic emissions could be realized by replacing internal combustion engine vehicles with alternative fuel vehicles (AFVs). However, the required electricity to drive the AFVs must be generated from renewable energies (REs).

Therefore, the second essay modeled the willingness to pay for electric vehicles (EVs) in four megacities of Iran. The results of the mixed logit model show that purchase price (46.40%), fuel type (24.05%), availability of charging station (12.88%), and nonmonetary incentive policies are the most influential factors for the willingness to pay. Moreover, potential consumers prefer a lower purchase price and lower fuel costs. The results of the market simulation confirm the effectiveness of combined policies over the single policy, which can be attributed to the heterogeneity among potential consumers (the different preferences and different importance assigned to each attribute) and the synergy effects of all the policies. The results of the latent class model demonstrate three different groups of consumers (indicating the substantial heterogeneity among them) which must be considered when designing transportation policies to increase the EVs' market penetration rate.

The third essay had dual objectives: 1. identifying and ranking the barriers to the development of REs in Iran, and 2. determining the most cost-effective REs from solar Photovoltaics (PV) wind power, and biomass. From the surveyed literature and interaction with experts, thirteen barriers were identified and categorized into five groups: economic and financial, social, cultural, and behavioral; political and regulatory; technical; and institutional. A comparative survey was performed to obtain the experts' opinion on the identified barriers. The results of the analytical hierarchy analysis show that the main impediments to expanding REs, in descending order, are economic and financial; social, cultural, and behavioral; technical; political and regulatory; and institutional. Moreover, the results indicate fewer barriers to the development of solar PV, followed by wind power, and biomass. Therefore, in designing supportive policies in the form of setting minimum targets for RE consumption, the government must pay more attention to solar PV as a cost-effective RE option. Finally, based on the systemic competitiveness model, the related strategies and action plans were proposed in four layers: the micro, meso, macro, and meta.
Keywords: green growth strategy, renewable energy, electric vehicles, mixed logit, autoregressive distributed lag, co-integration regressions, analytical hierarchy analysis

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Overview

1.1. Problem description

Global warming caused by environmentally inconsistent manufacturing activities has been one of the most challenging concerns within recent decades. To overcome the concern it is needed that international organizations, researchers, and policymakers play a pro-active role (Acheampong, 2018 and Acheampong, 2018). Specifically, two decades after the first Rio Summit, all countries encountered a double challenge: increasing economic opportunities for the growing population and dealing with environmental issues. In this regard, the concept of "green growth" has emerged to be a core policy instrument to use opportunities to realize the two aforementioned objectives simultaneously (Hickel & Kallis, 2020).

As an energy-driven economy, Iran needs to integrate "green economy" into "energy sector" (Ardestani et al., 2017). Based on the latest data available on the website of Statistical Center of Iran, in 2017, 60.4% of manufacturing value-added belonged to energy-based industries including chemical and petroleum products (38.5%) metals and non-metallic products (21.9%). However, these industries are backbone of the manufacturing sectors and cannot be considered as the starting point to reduce the energy consumption and therefore to control the environmental issues.

Therefore, the other energy consumers and high emitting sectors must get more attention as a starting point to design and structure the green growth strategy. To this end, the energy consumption and CO_2 emissions by sectors are illustrated in Figures 1.1 and 1.2.

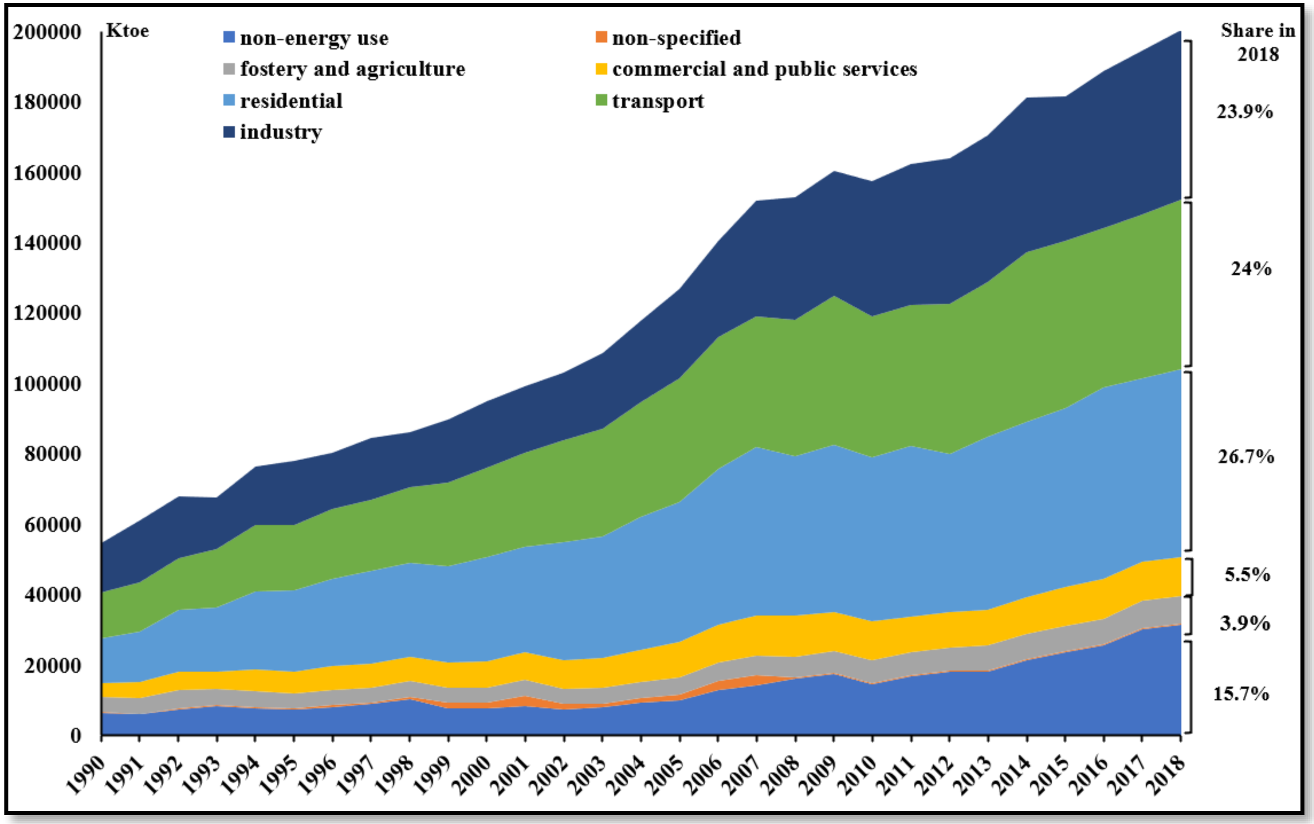


Figure 1.1. Final energy consumption by sector (1990-2018)

Source: (International Energy Agency, 2020)

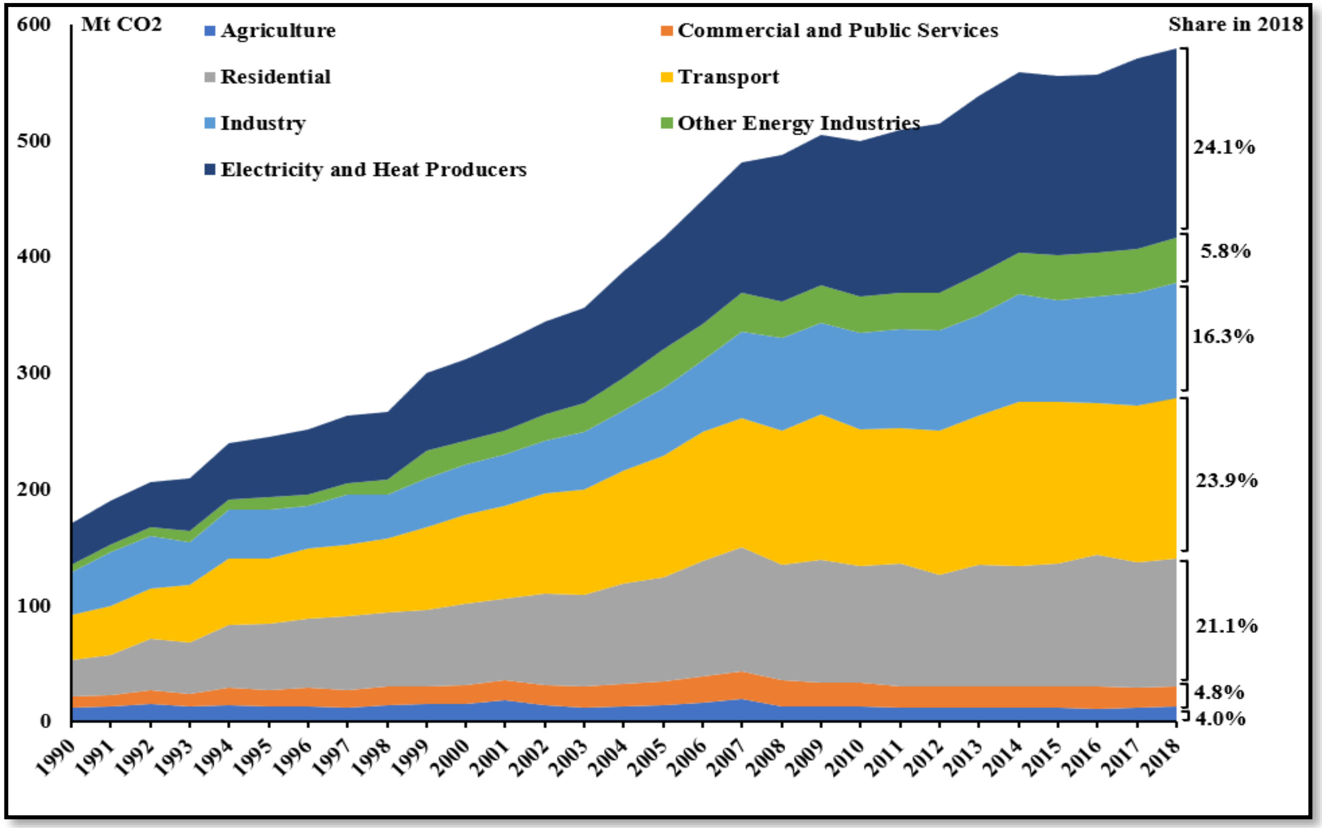


Figure 1.2. CO_2 emissions by sector (1990-2018)

Source: (International Energy Agency, 2020)

As illustrated in Figure 1.1, between 1990 and 2018, the final energy consumption in Iran has increased at an annual average rate of 4.6% (from 54712 to 200299-kilo tones oil equivalent). Breaking down the final energy consumption by sector showed that in 2018, the residential sector (26.7%) is the largest energy consumer sector followed by transportation (24%), and industry (23.9%). As shown in Figure 1.2, in the same period, total CO_2 emissions have increased 3.4 times, from 171 to 579 million tons. Among energy consumer sectors, the electricity and heat producers (24.1%), followed by the transportation sector (23.9%), have emitted the highest amount of CO_2. This fact can be explained by the dominant share of fossil fuels in electricity generation mix (Figure 1.3).

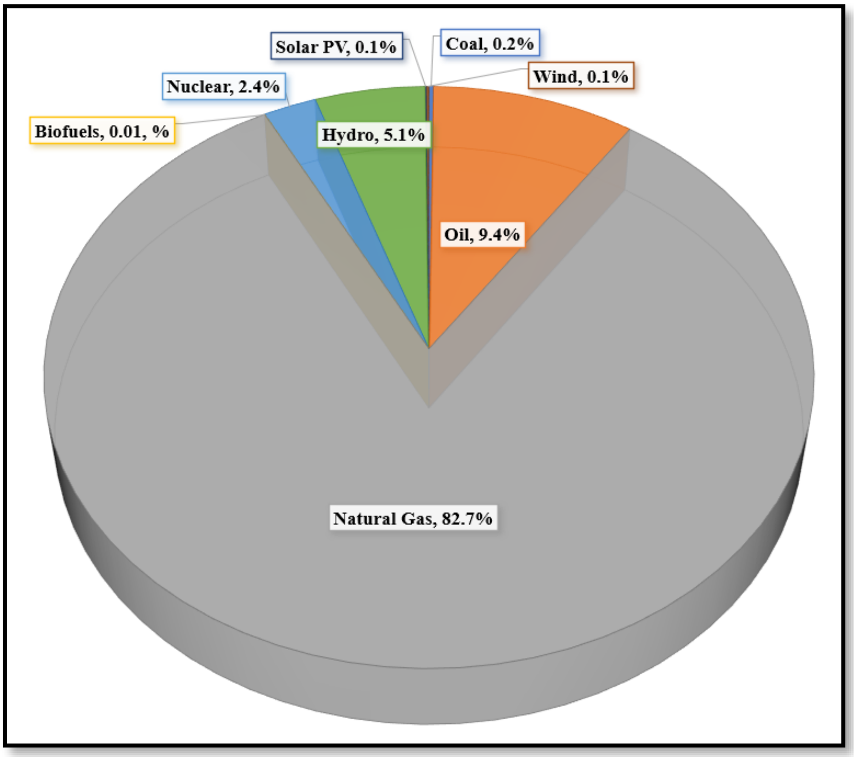


Figure 1.3. Electricity Generation by fuels, 2018 (%)

Source: (International Energy Agency, 2020)

Referring to Figure 1.3, fossil fuels accounted for 92.3% of total electricity generation (285.9 TWhs) in 2018. Furthermore, the share of hydro, nuclear, RE in electricity generation is 5.1%, 2.4%, and 0.21%, respectively.

Therefore, increasing energy security, controlling the environmental side effects of burning fossil fuels, and achieving sustainable economic growth could be reached through reshaping policies in the power and transportation sectors. To this end, measuring the elasticity (sensitivity) of CO_2 emissions regarding the transportation sector (number of vehicles on the road) is required. Therefore, in the first essay, the short and long-term relationship between the transportation sector and environmental degradation are analyzed, and a causal relationship is identified.

However, along with the expansion of renewable sources over the horizon, switching from conventional-powered-based vehicles to electrified ones has gained more attention as an alternative to reduce high dependency on fossil fuels in the transportation sector and to control emissions caused by road traffic. However, it is crucial to state that designing the appropriate related transportation policies requires considering both sides of the market, called supply and demand sides. At the supply side, the government, policy-makers, and automakers are planning to produce electric vehicles and penetrate the market. For instance, the government has taken some measures to improve air quality and enhance fuel efficiency and has a master plan to electrify the transportation sector. However, investigating the consumer's tendency toward the decarbonized transportation sector plays a crucial role in increasing the acceptance rate of EVs. Therefore, using the SP, the second essay attempts to identify the determinants of willingness to pay for EVs in four megacities of Iran and the effective government incentive policies to increase its market share.

It is noteworthy to mention that number of emissions from EVs depends on sources that are used to generate electricity to charge the electric battery. The more electricity is generated from renewable energy sources, the less CO_2 emits. On the other hand, the dominant share of fossil fuels in the electricity generation mix indicates the existence of barriers to the development of these new technologies. Therefore, employing the AHP model, the third essay identifies and ranks the obstacles to the expansion of the three most suitable RES in Iran, called solar PV, wind power, and biomass to identify the most cost-effective renewable energy option.

The remainder of this chapter is structured as follows. The next section covers the current status of the auto industry in Iran. The used methodologies are then presented. Finally, the thesis outline is exhibited.

1.2. Iran's auto industry at a glance

The current situation of the auto industry is discussed in this section. To this end the evolutionary path of auto industry is summarized in Table 1.1.

Table 1.1. Iran's automotive Industry evolutionary path over the time

Period	Description
1969-1978: lack of targeted and coherent program	1963-1974: foreign exchange reserves shortage; encouraging the private sector to industrial investment through securing investors security; 1974 onward: import due to foreign exchange revenues. **Main problem**: duplication, lack of construct base and low production level.

Period	Description
	Strategy: providing required infrastructure to achieve assembly industry in order to compete with expanding import and meet domestic needs.
1979-1989: effort to survive	Investing in commercial vehicle (bus and track) and ignoring the passenger vehicle, an inappropriate environment for auto-parts investment and outflow; control and freezing sale price, lack of investment. **Strategy**: Conservation for Survival.
1990-1993: the lost golden opportunity	Executing economic adjustment policies, an abundance of currencies, paying $2 billion for importing164 thousand vehicles, encouraging foreign goods usage instead of investing, guaranteeing the import of spare parts for next 20 years.
1994-2004: renascence of auto industry	Enhancing and launching engineering design and auto-parts provider companies, utilizing the idle capacity in the other industries, establishing and developing the auto-parts, expanding the ability to design a vehicle and its components (parts), enhancing local content and reducing the dependency on foreign exchange and getting self-sufficiency, modifying the production structure through privatization, paying attention to workforce as the main capital, establishing the development and testing centers for various types of vehicles and parts, designing (1996) and producing the first national car (2001), adopting common platform with Renault (X90 in 2003 in the form of joint venture between Iran Khodro, SAIPA and Renault and adopting a multi-brand (domestic and foreign) strategy in this year.
2005 onward	Changes in the political approach and appearing some problem to realization of the common platform strategy with Renault, attracting foreign investment and collaboration with automaker and auto-part makers around the

Period	Description
	world, reiteration on self-sufficiency approach (automobile, engine, platform and national brand), designing and producing the second and third national brand, stimulating demand by providing soft loan in lower rate than what market does to customers despite placing more pressure on the automakers, occurrence of liquidity crisis and progressive trend in financial cost due to the pre-selling, excessive increase in costs caused by creeping inflation, Financial repression due to the restriction on product pricing, currency problems (three-fold increase in exchange rate and transfers) caused by economic sanction and therefore stiff reduction in production, the recession in the market and the emergence of the overcapacity, reducing the profitability. However, thanks to suspending the economic sanction and Geneva agreement, domestic auto manufacturers (and auto-part makers) could sign joint venture contracts with the foreign companies.

Briefly, the development of automotive industry could be divided into seven stages as 1. Assembly; 2. Enhancing the Auto Parts, 3. Mass production; 4. Establishing design and development bases for parts and automobile; 5. Designing and producing new automobile (national brand) and renewal of auto parts networks and launching export; 6. Designing and providing required equipment for production line; 7. Suffering from economic sanction and utilizing the opportunities after suspending sanction and tightening collaboration with foreign automakers in the form of Joint Venture.

1.2.1. The significance of the auto industry

The most significant importance of the automotive industry in Iran could be realized by studying its economic performance like the contribution to industrial value-added and industrial employment. Therefore, it could be concluded that this industry plays a crucial role in the economy. More precisely, it provides jobs for 11% of industrial labor force and contributes to 10.8% of the industrial value-added in 2018 (see Figures 1.4, and 1.5 respectively).

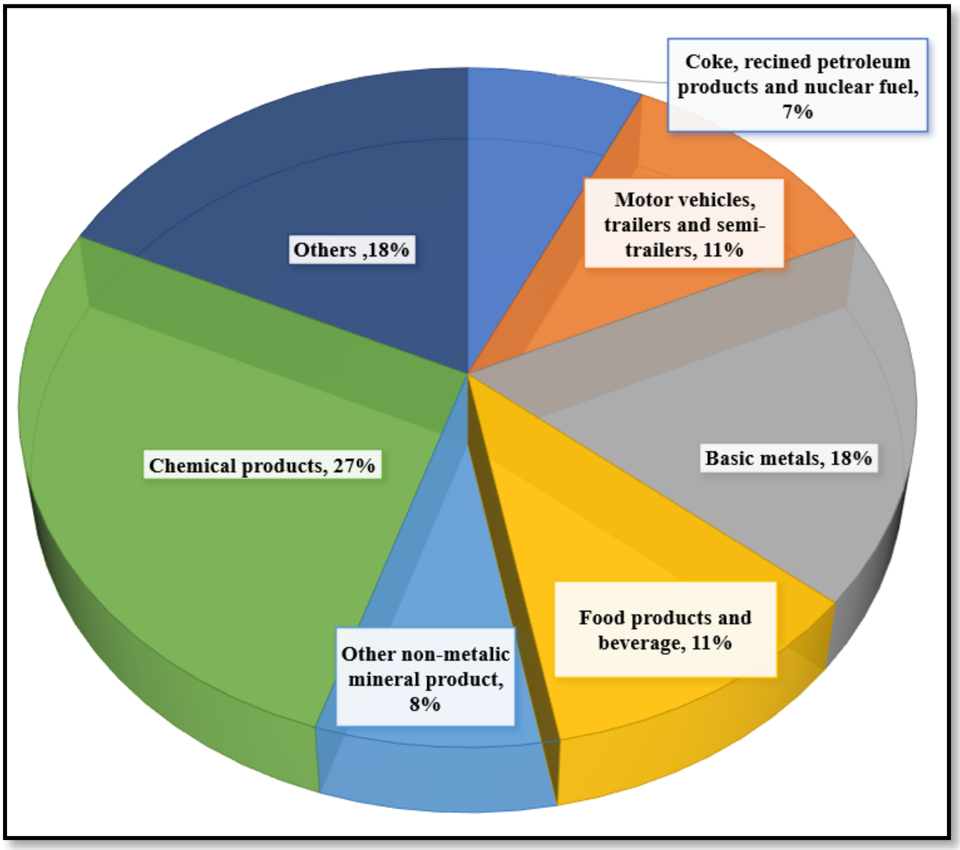


Figure1.4. The Share of Auto Industry in industrial value added 2018 (%)

Source: Calculated by the author based on SCI [Statistical Center of Iran]

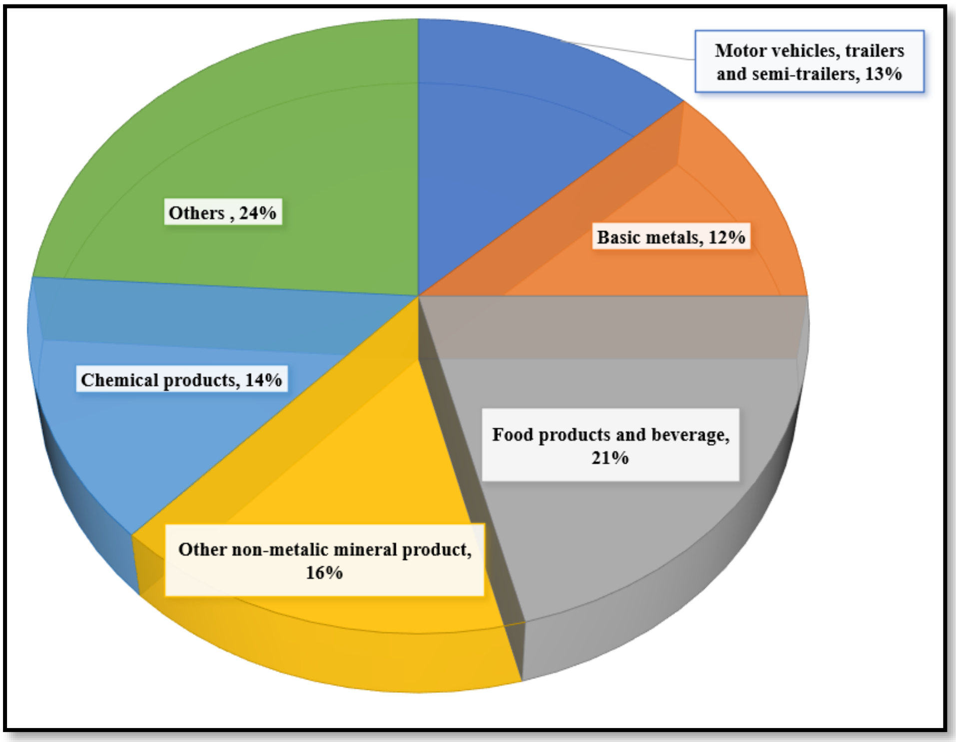


Figure1.5. The Share of Auto Industry in industrial employment 2018 (%)

Source: Calculated by the author based on SCI [Statistical Center of Iran]

Based on the Figures 1.1 and 1.2, the automotive sector ranks 3rd in terms of share in industrial value added after chemical products and basic metals and the 3rd highest industry in terms of the share in industrial employment after food products & beverage and other non-metallic mineral product. So, the automotive industry is considered as a strategic and driving force in Iran economy.

1.2.2. Production and import

The rapid increase in oil revenues during the 1970s was a major boost to both auto assembly and car imports into Iran. Production and import trends during the 1969 to 2017 are drawn in Figure 1.6.

Based on the trends observed in Figure 1.6, production/import of the automobile in Iran can be divided into five periods as follows:

i. **The Primary Growth Period (1969-1977)**: through these years, the industry output was expanded quickly reaching 180,000-passenger cars by the end of the period, and entrepreneurs in private sector searched for launching automobile and auto-parts factories in the form of assembly and domestic production. At the same time, due to increased oil revenue, which realized in 1973, continuous growth of imports was experienced during the same time.

ii. **Up and Downs Period (1978-1994)**: due to the revolution (1979) and nationalization of the major facilities and Iraq-Iran war, which led to decreased automaker's access to foreign currency needed for importing parts, the primary growth slowed down. On the other hands, Production levels deteriorated in quantitative and qualitative terms until the early nineties in a circumstance filled with revolutionary self-sufficiency slogans. Furthermore, the import of autos increased immediately after the War (which ended in 1988).

iii. **Flourishing Period (1995-2011):** the auto industry was revitalized in the mid-1990s while remaining under government control (under IDRO). The production of cars from domestic parts and in the form of importing CKDs and SKDs has rapidly expanded since then. The number of cars (both produced/assembled) was less than 100,000 before the mid-1990s, while by 2011, reached 1.6 million units. By 1995 through 2006, due to adopting the supportive policy by the government specifically in the form of import prohibition, the import fell to zero.

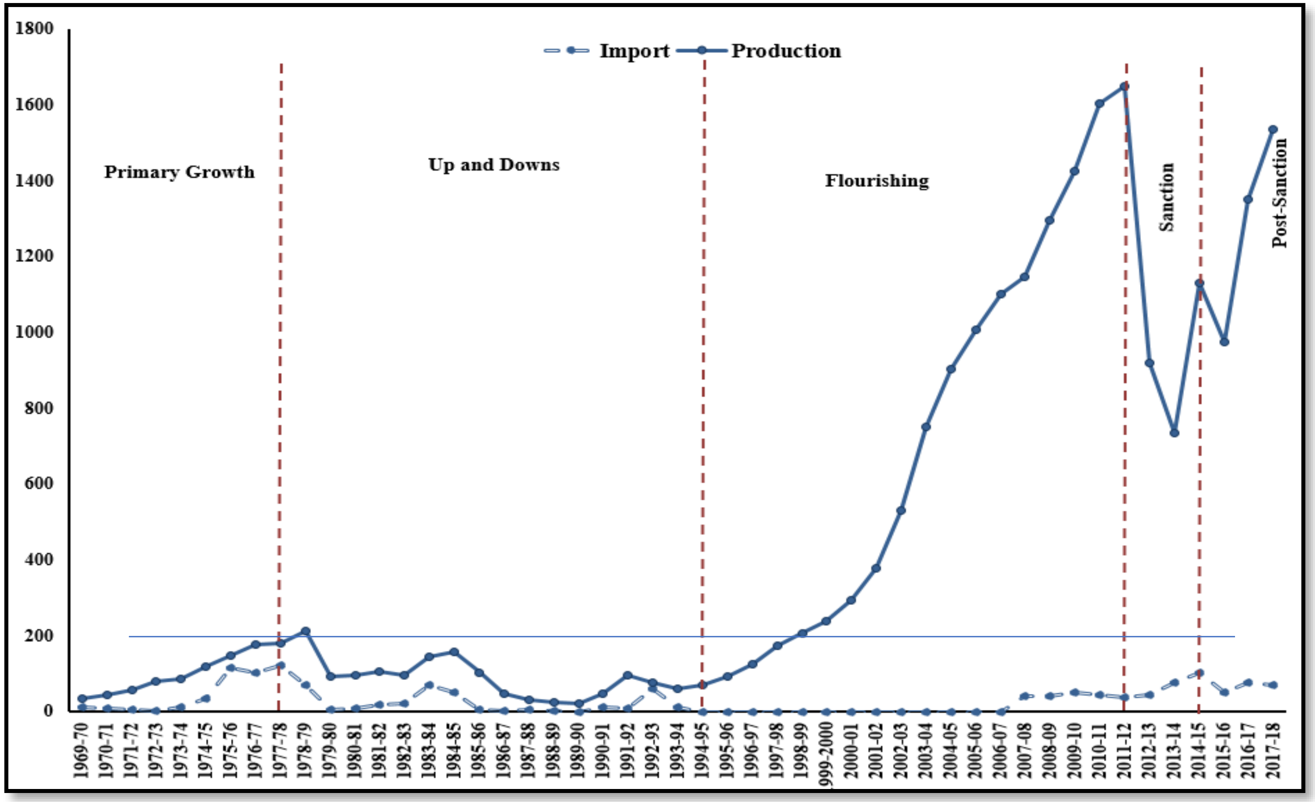


Figure1.6. Production and Import Trends in the Iranian Auto Industry, 1969 to 2017 (‘000 units)

Source: Productions: Bureau of Autos Industries and Power-train, 2018, Import**s:** CAI (Customs Administration of Iran), 2018

iv. **Sanction Period (2012-2014):** because of imposing an international sanction on Iran's automotive industry on June 30, 2012, prohibiting the sale of materials and auto-parts to Iranian manufacturers, and complete pause in the operations of foreign brands (limiting the Iranian assembler’s access to required auto-parts), the total production declined dramatically to 921,000, and 737,000 units in 2012 and 2013, respectively. Therefore, assemblers could not achieve their production goals. For example, in 2013, only 60.8 percent of production goals were obtained.

v. **Post- Sanction Period (from 2014 up to now):** lifting the sanction on Iran's automobile industry on January 2014 along with the effects of the JCPOA, increased European Auto Manufacturers confidence and interest in the automobile market and they renewed their relations with auto-part manufacturers. Termination of nuclear-related sanctions in 2014 led to increasing the production by 53.5%. However, in 2015, although nuclear negotiations resulted in JCPOA, production declined most likely because of the unrealized expectation of consumers for lower prices. At the same time, the import of auto maintained its growing trends (Razavi & Alaedini, 2018). In 2016, and 2017, automotive production increased due to the presence of foreign investors such as Hyundai into the automotive industry and shifting the auto industry to the more competitive structure. Under the new situation, product diversity was improved, and competitive conditions were formed in sales and installment sales was facilitated.

1.2.3. The Market structures

The structure of the auto industry in Iran could be considered as a *duopoly* and its development over the past fifteen years has been owed to the productions of two large companies, controlled and until recently wholly owned by the government. "IKCO" and "SAIPA Group," overwhelmingly dominate the scene. The abovementioned companies controlled about 90 percent of the market in passenger car market and 64 percent of commercial vehicle in 2017 (see Figures 1.7 and 1.8).

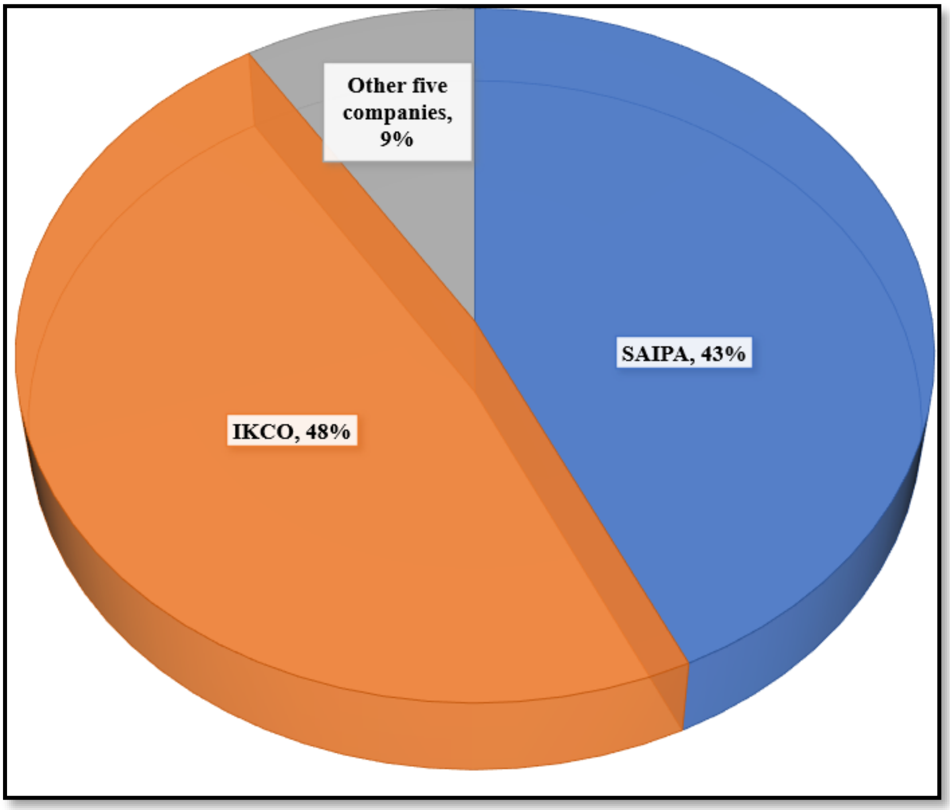


Figure1.7. Main players in the Passenger Cars Market 2017 (%)

Source: Calculated by the author based on the Bureau of Autos Industries and Power-train, 2018

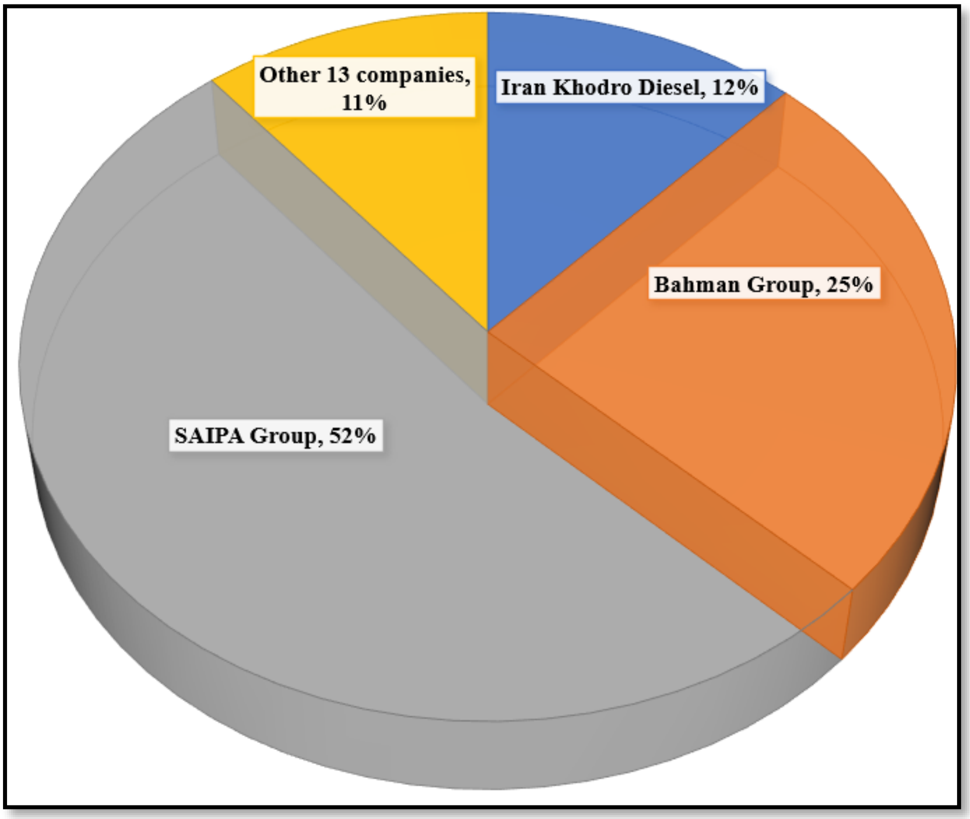


Figure1.8. Main players in the Commercial Vehicles Market 2017 (%)

Source: Calculated by the author based on the Bureau of Autos Industries and Power-train, 2018

In the commercial segment, SAIPA Diesel (51.5%), BAHMAN Group (25.4%) and Iran KHODRO Diesel (12.5%), have a dominant role in the market (89.3 percent), while remaining 10.7 percent belongs to other 13 companies. Therefore, the figures confirm the high concentration in automotive market in Iran, which is caused by executing supportive policies by government such as imposing high tariffs on imported vehicles and customs duties on auto-parts import.

However, it is worthwhile to mention that passenger vehicles (produced /imported) are driven by gasoline or dual fuel (gasoline/CNG), indicating the lack of diesel or other fuel alternatives for the vehicles in this country (Eskafi, 2016), operated beyond their standard life cycle (Zarifi et al., 2013) accounting for 24% of CO_2 emissions related to fossil fuel combustion in 2019, which is much more than what's expected. Overcoming this issue cannot be realized through preventive tools such as fines, tax etc. Therefore, enhancing the competitiveness of this industry requires an expanding scale of production, which in turn needs market expansion. In this regard, the government and policymakers must shift towards renewable energy in line with global trends. Therefore, the green-growth strategy must pursue considering the transportation sector.

1.2.4. Electric vehicle

The lack of a single trustee is one of the most influential factors in the failure of developing new technologies such as EVs in Iran. The Ministry of Industry, Mine, and Trade of Iran, as a trustee and shareholder in the auto industry, has not taken effective measures to produce EV. Although IKCO and SIPA Group, as the dominant car manufacturers, have carried studies out, these vehicles have not been commercialized yet. It is noteworthy to mention that expanding electric transportation depends on the government's attitude concerning that issue, which can be traced in law and regulation (Ataei, 2014). In this regard, the legal references and high-profile documents are illustrated in Table 1.2.

Table 1.2. Legal references and high-profile documents in EV

Title/ Year	Policy Description/ Legal Reference
Law on the development of public transportation and fuel consumption management (2007)	The government is obliged to take required actions to expand intra-city and suburban transportation and management on fuel consumption to optimize transportation services (through modifying and developing the rail transportation network and speeding it up, electrifying railway lines, integrating and regulating transportation management, correcting price, improving road traffic safety,

Title/ Year	Policy Description/ Legal Reference
	removing old light and heavy vehicles (passenger and freight), converting diesel and gasoline- and diesel-powered cars to dual-fuel one, reforming the administrative procedure, applying information and communication technology, applying land use planning, imposing traffic restrictions, training and culture-building, optimizing energy consumption (through supplying gasoline and diesel in the transportation, industrial, and agricultural sectors with the priority of smart fuel cards, constructing gas stations, supporting the managing fuel-consumption innovations and patents), optimizing vehicle production (through producing gas vehicles, **supporting production of electric, hybrid and low-consumption vehicles**, standardizing light and heavy-duty vehicle production and motorcycle in fuel consumption and emission reductions), stop supporting the gasoline and diesel engines, before the beginning of 2012. Clauses 1 and 2 of Article 2 allow the government to take the following actions to implement the provisions of Article (1) 1. Provide grants to non-governmental sectors related to the goals of this law. 2. Impose discount on customs duties and commercial profit on import of public transport fleet, different types of vehicles such as low consumption, gas, gas oil, **electric and hybrid**, and related parts and equipment.
Law on removing the barriers of competitive product and improving the financing system (2015)	**Section B Article 12** Allowing all ministries, particularly the Ministry of Petroleum, the Ministry of Energy and their subsidiaries, public institutions and organizations to invest 100 billion dollars and 500 billion local currency (Rials) in the following projects: • Optimizing energy consumption in the different sectors including industry with the priority of

Title/ Year	Policy Description/ Legal Reference
	energy-intensive ones, public transportation, rail transit (urban and inter-urban), and building; • Expanding the use of renewable energy; • Increasing the usage of compressed or liquefied natural gas or liquefied petroleum with the priority of megacities and major interurban routes; • Producing or replacing the fuel-efficient or electric vehicle with old ones.
The clean air act (2017)	**Article 9** The Ministry of the Interior, in cooperation with the Ministry of Industry, Mine and Trade, the Ministry of Economic Affairs and Finance (the Customs Administration of the Islamic Republic of Iran), is responsible for renovating the urban public transport fleet with priority given to cities with over two hundred thousand people within five years, through grants, subsidies, eliminating commercial profits of import of hybrid vehicle/ motorcycles. Note. The locally produced hybrid vehicle, motorcycles, and EVs are exempt from value-added tax.

According to Table 1.2., despite the existence of supportive laws for EVs in Iran, there is not enough effort to implement them.

1.3. Energy status in Iran

Energy consumption is a crucial driver for economic and social development (Cai et al., 2018). Nevertheless, the energy sector in Iran encounters difficulties in achieving the goals of sustainable development, which could be listed as follows:

1. Heavily reliant on conventional fuels, despite holding high potential in renewable energy. Iran is a country rich in recoverable reservoirs of oil and natural gas. Precisely, Iran accounted for 9% of total recoverable reserves of oil and

condensate (Figure 1.9) and 12% of the Organization of the Petroleum Exporting Countries (OPEC) reservoirs in 2019 (Figure 1.10).

As shown in Figure 4.9, owning 155.6 thousand million barrels recoverable reserves of oil and condensate in 2019, Iran ranked as the worlds' fourth-largest oil holders, followed by Venezuela, Saudi Arabia, and Canada. The ratio of onshore crude oil reserves to the offshore (mostly located in the Persian Gulf) is 70 to 30 percent (Gholamhasan Najafi et al., 2015). Though the exploration of oil has been stopped in the Caspian Sea, Iran possesses proved reserves there as well.

As illustrated in Figure 4.10, holding 12% of OPEC oil reserves, Iran ranked third, followed by Venezuela (28%) and Saudi Arabia (24%). The remaining ten countries account for 36%.

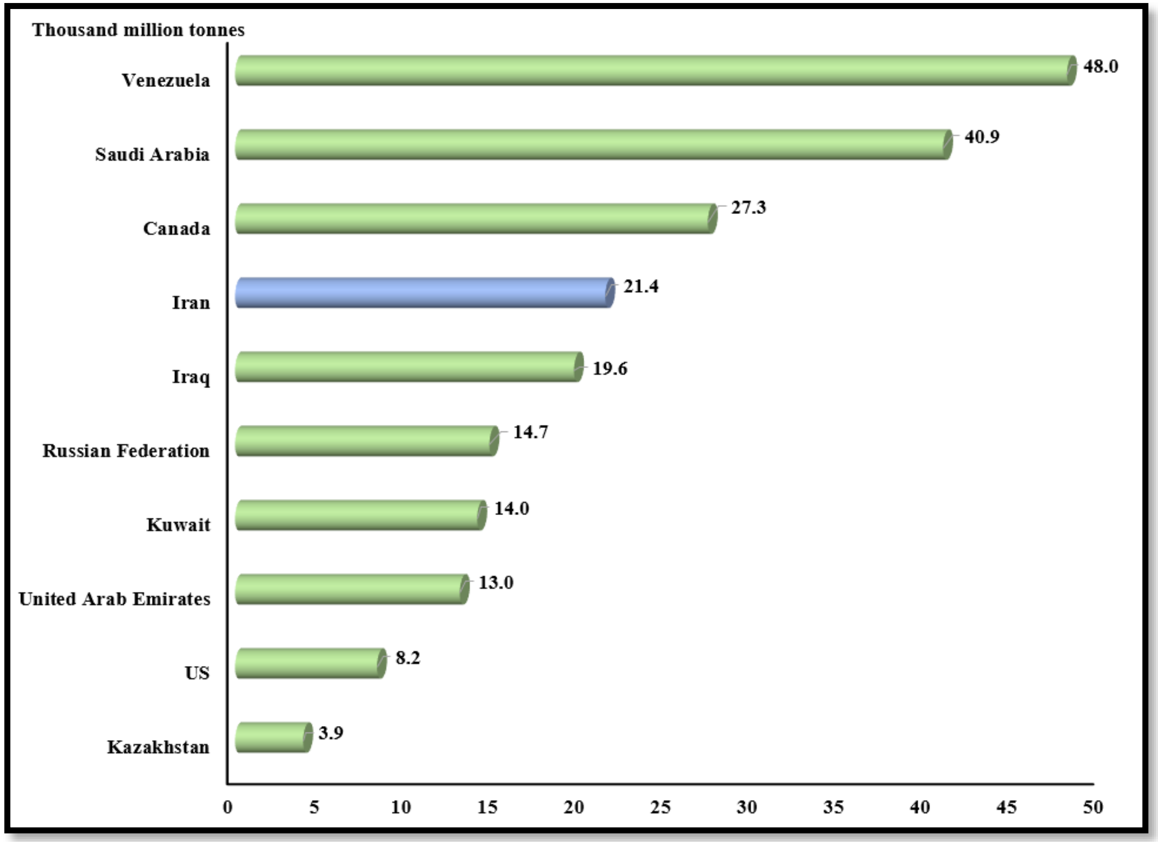


Figure 1.9. Iran ranked as the world's fourth-largest oil reservoirs (2019)

Source: (BP, 2020)

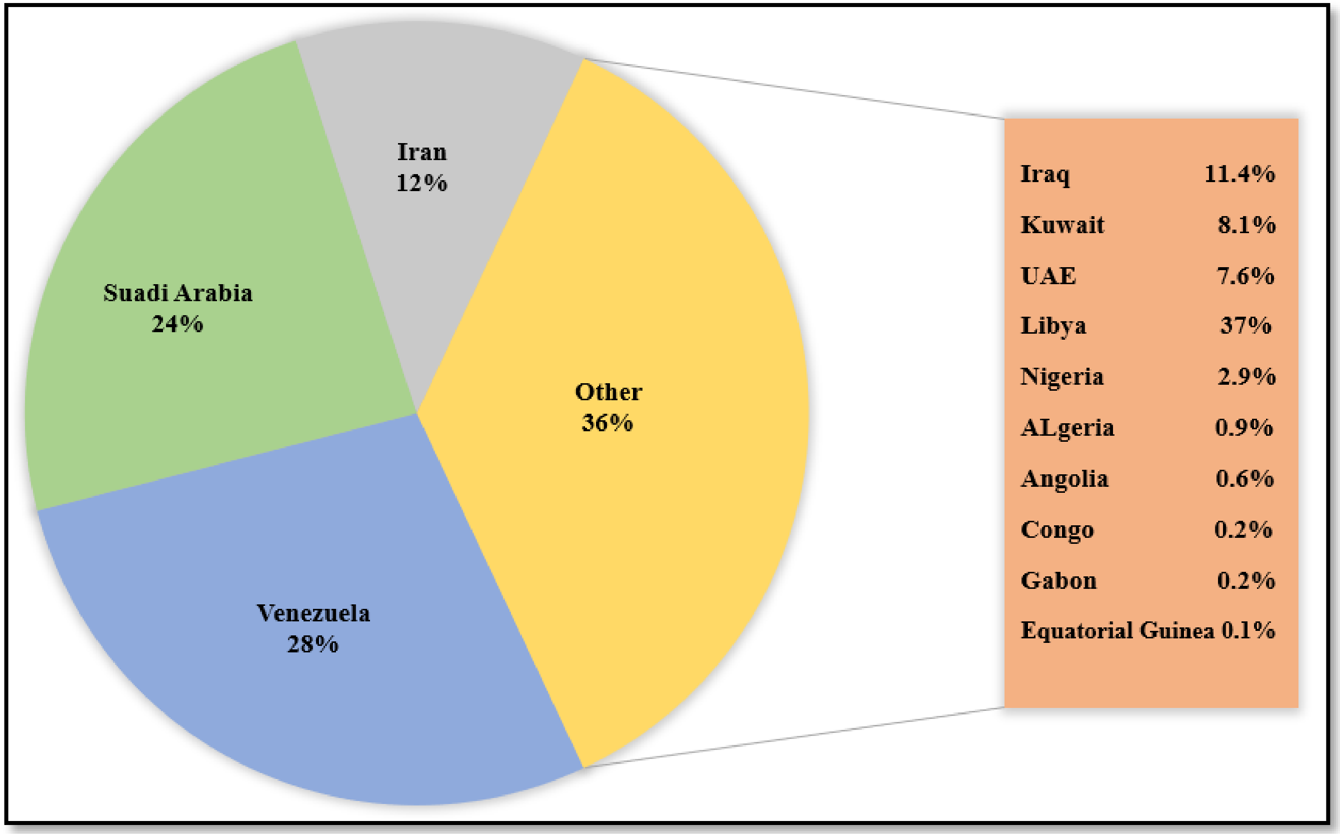


Figure 1.10. Iran held the third oil reservoirs of OPEC countries (2019)

Source: (BP, 2020)

Owning 1130.7 trillion cubic feet natural gas reservoirs (16.1% of total gas reserves), Iran ranked as the world's second gas reserves holders in 2019 behind Russian Federation (Figure 1.11), and it held 48% of OPEC gas reserves (Figure 1.12). It is predicted that 40% of natural gas reserves in Iran are held by the South Pars, the largest Iran's natural gas field (Abbaszadeh et al., 2013).

In 2019, the total consumption of conventional fuels comprising oil, natural gas, and coal reached 1964-million-barrel oil equivalent in Iran. This amount accounted for 97.4% of total primary energy consumption (BP, 2020).

as depicted in Figure 1.13, natural gas had the dominant share (65.2%) in the energy mix of Iran in 2019, followed by oil (31.8%) and coal (0.4%).

2. Allocating high subsidies for fossil fuels to keep fossil fuel prices at a low level, and therefore to assure the affordability and availability for all income levels in the country. Precisely, in 2018 the government has granted $26.6 billion, $26 billion, and $16.6 billion to oil, natural gas, and electricity, respectively. Hence, Iran attained first place in providing subsidies to fossil fuels around the world, which accounted for 15 percent of its total GDP (*IEA World Energy Outlook*, 2018). Besides, it has led to a tremendous waste of energy (inefficient energy consumption) and has reduced the tendency to the explore alternative energy sources like renewable sources.

3. Iran is suffering from environmental issues, which are partly caused by extensive use of natural resources, especially conventional sources, and rapid population growth. Based on the latest data available on the World Bank website, Iran's population has increased 3.8 times between 1960 and 2019.

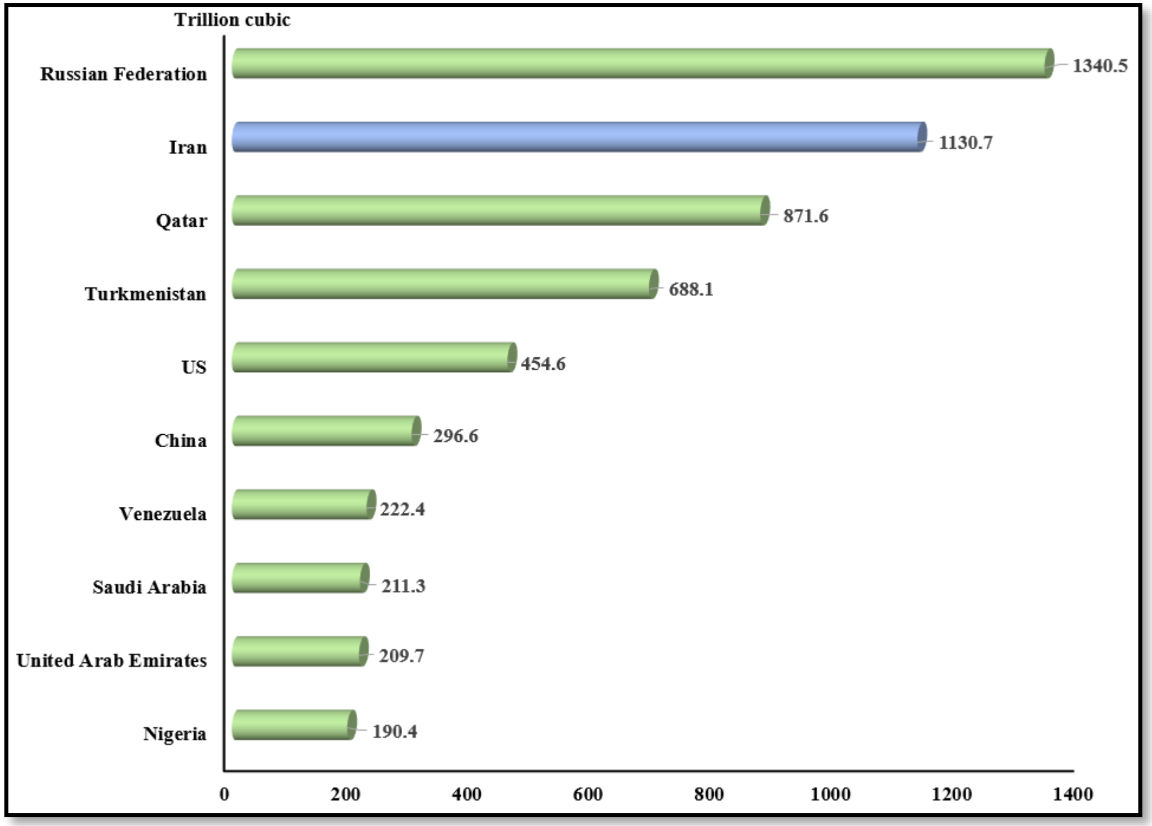


Figure 1.11. Top 10 gas reserves holder countries in 2019

Source: (BP, 2020)

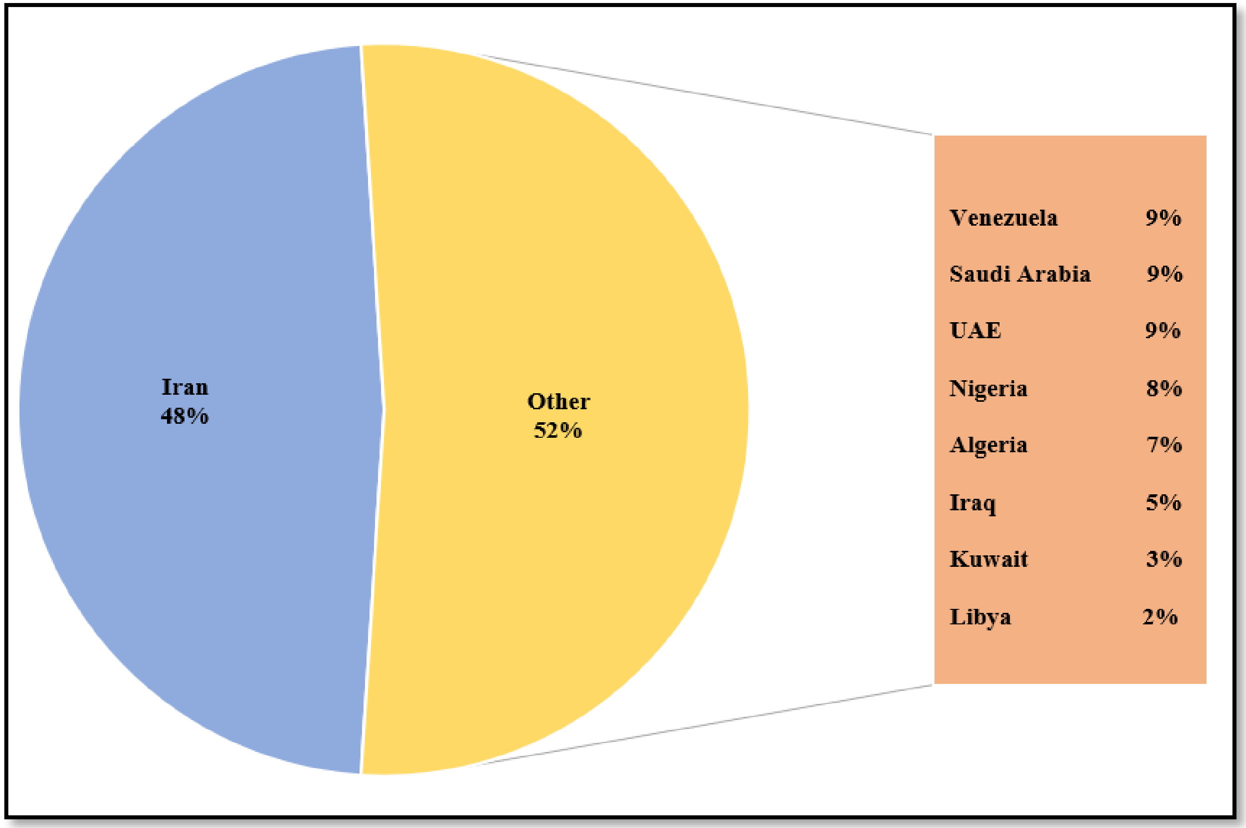


Figure 1.12. OPEC gas reservoirs 2019

Source: (BP, 2020)

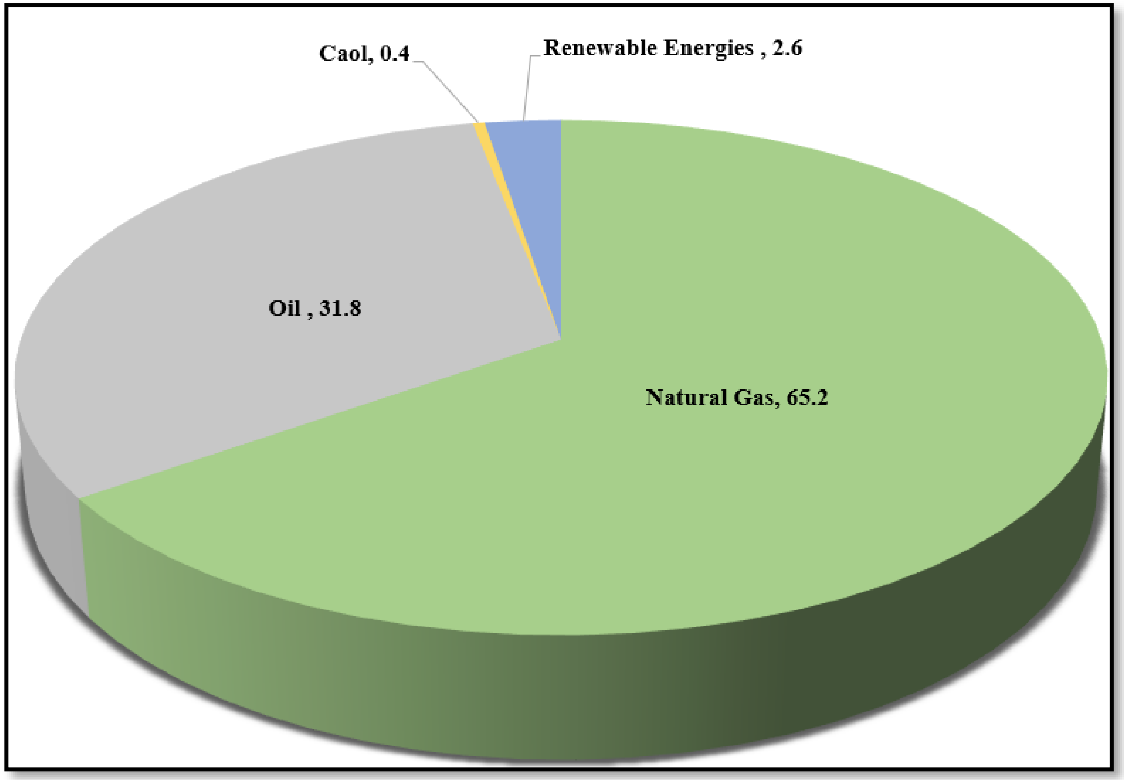


Figure 1.13. Breakdown Iran's total energy consumption by Fuels, 2019 (%)

Considering the nuclear and hydropower as renewable energy technologies

Source: (BP, 2020)

Iran also has a high potential in REs including hydropower, solar energy, wind energy, geothermal, biomass, and marine. Detailed information on the potential of REs by type is provided below.

- **Hydropower**: water is one of the most important types of REs in Iran. Due to the various advantages of employing hydropower besides electricity generation such as socioeconomic, geological, and agricultural benefits, constructing dams to control flood, to supply irrigation water, and to create a job in various sectors is getting more attention (Mollahosseini et al., 2017). However, water shortage is one of the most challenging issues in Iran, and the potential of large hydroelectric power plants in electricity generation is low (Jahangiri et al., 2018). Hence, REs must be considered as alternative sources for the long-run horizon.

- **Solar energy**: Located on the Sun Belt (Fadai et al., 2011), covered by numerous deserts (Khojasteh et al., 2018), and exposure to the sunlight 17% higher than the global average (Tavana et al., 2019), Iran has lots of suitable areas to deploy solar energy. Indeed, it enjoys 2800 sunny hours yearly; the sunny hours in spring, summer, autumn, and winter are 700, 1050, 830, and 500 h, respectively (Ghorashi & Rahimi, 2011). Due to the technical simplicity of solar energy, it is a fascinating option to be developed.

- **Wind energy**: Besides owing enormous deserts, Iran is a mountainous land, with the Caspian Sea on its north, and the Persian Gulf, and the Oman Sea on its southern part. These situations show the availability of high local wind energy potentials. Moreover, this country has several tropical winds flows, the Western flow from the Atlantic Ocean and the Mediterranean Sea, and the Central flow from the Indian Ocean during summer and the central flow from Central Asia during winters (Ghorashi & Rahimi, 2011). The cumulative installed wind power capacity in Iran has increased from 9 Megawatts to 302 Megawatts in 2019 (BP, 2020).

- **Geothermal**: Iran holds numerous volcanoes, regular ground movements, and warm water streams due to being located on the world's thermal belt (Ghorashi & Rahimi, 2011) and it has huge potential in geothermal specially in the northern areas (Gholamhassan Najafi & Ghobadian, 2011).

- **Biomass**: Around 7% (11 million ha) of land in Iran is covered by forests (Mollahosseini et al., 2017), while the share of pasture and agriculture in the total land is more than 52% (Mohammadnejad et al., 2011). However, due to the water shortage (lack of sufficient water supplies), around 22% of agricultural land in Iran is not under operation or use (S. E. Hosseini et al., 2013).

- **Marine**: The abundantly available wave, thermal, and tidal energies in Iran can be attributed to the long coastline with the Persian Gulf and the Caspian Sea (Afsharzade et al., 2016).

Developing renewable and modern energy sources and optimizing the utilization of their potential has drawn the attention of the government. For instance, the government plans to increase the share of

REEs excluding hydropower in the total energy mix amounts to 10% by 2025 (Bahrami & Abbaszadeh, 2013).

1.4. Energy policy in Iran

As the only upstream document in the energy sector, "General policies of the regime in the field of energy" has no strategic orientation. However, efforts were made to strategize for this document in the form of paragraph "b" of Article 125 of the Fifth Development Plan Law, according to which the government is required to develop a national energy strategy document for a period of twenty-five years within a maximum of six months after the Development Plan approval. However, this strategic plan was not implemented. Subsequently, this was pursued in Article 45 of the Sixth Development Plan Law in the form of the requirements for the development of an executive plan of the country's comprehensive energy plan within a year, which was finally formulated and announced in April 2020. However, despite the quantitative targeting in order to balance the various energy sectors and due to the lack of an upstream strategic document, its implementation in practice is ambiguous. Prerequisites for acquiring shares, such as the need for an independent and codified regulator, attention to the role of human capital, incentives for investment in research and development as well as technology transfer (technology), etc. have been ignored in this plan. Overall, it can be said that although there is energy targeting in Iran, it still lacks energy policy. The most important challenges in Iran's energy policy can be summarized as follows:

i. **Lack of a single authority for the energy sector:** One of the most important problems of the country's energy sector is the lack of a single authority to pursue energy-related issues. Lack of coordination between government agencies, planners, policy makers and implementers in this sector, including the Ministry of Oil and its subsidiaries, the Ministry of Energy, the Atomic Energy Organization, the Management and Planning Organization, etc., has caused numerous problems culminating in wastage of resources in various sectors.

ii. **Oil production policy dependence on to the need for foreign exchange earnings from its exports:** The dependence of the economy and government revenues on crude oil exports is one of the external factors that have affected the country's production program from oil fields. Governments have always tended to extract as much oil and gas fields as possible due to their dependence and on oil revenues, thereby ignoring protective production in oil fields. The reliance of the budget on oil revenues, fluctuations in revenues and annual budgets due to changes in oil prices and oil exports, increasing government size, chronic inflation in the economy are all signs of budget dependence on oil revenues.

iii. **Lack of comprehensiveness and recentness of the country's energy information infrastructure:** The country's energy information is facing shortcomings one of which is the lack of comprehensive information. The existing balance sheets only include the energy production and supply side and do not provide information on consumption. Second, the issuance of separate balance sheets by the Ministry of Oil and Energy which contain differences in key figures. Third, the lack of up-to-date information. In fact, balance sheets and other information are published every year after one or two years. These shortcomings, while disrupting the decision-making process of the relevant institutions, hampers the decision-making system consisting of academic departments, think tanks and other institutions due to lack of information available to provide analysis.

iv. **Lack of proper decision-making structures and elite participation in the energy sector:** As mentioned in the previous section, decision-making structures in the energy sector face many weaknesses. First, the lack of comprehensive, accurate and up-to-date information as a basis for analysis and decision-making, and Second, not considering the position of decision-making institutions such as think tanks, universities and the like in the decision-making system of the country's energy sector.

v. **Lack of attention to renewable energy:** There is no necessary planning in the country to exploit existing renewable energy sources such as solar energy, wind, geothermal, etc., and these resources have a small share in primary energy production and power generation. However, due to its strategic location, Iran has a large capacity to exploit these resources.

vi. **Weaknesses in the design of energy efficient markets:** Efficient market design serves as the core of all energy efficient systems by creating a healthy competitive system in which not only the presence of the private sector is possible, but also the macroeconomic and socio-economic goals of the energy sector, including infrastructure are realized. This obvious weakness, along with other effective factors, has led to a small presence of the private sector in this area.

vii. **Lack of the private sector investment in downstream oil and gas industries:** Despite the high capacity in terms of oil and gas reserves, the value added of this sector has not received much attention from the private sector, which can be attributed to the lack of appropriate industrial policy for value chain development (including pricing policies, licenses, technology policies, etc.).

viii. **Restrictions on access to new technologies:** One of the most important restrictions on the development of technologies in the energy sector is the industries' limited access to new technologies due to sanctions. Given that these technologies are exclusively owned by a few international companies, it seems very difficult to obtain them in the face of sanctions.

ix. **Restrictions arising from sanctions:** Access to international financial resources, access to new technologies and interaction with international companies and taking advantage of their technological, managerial and capital potential are restricted in the face of sanctions. Moreover, oil and banking sanctions have also affected the country's oil production and exports.

Therefore, the development of a comprehensive strategic energy portfolio needs to address the above challenges (Imamiyan, S.H., 2017).

1.5. Methodologies

To examine the short- and long-term environmental impacts of energy mix and transportation sector, the ARDL and the ECM are employed. However, three co-integration regressions, i.e., FMOLS, CCR, and DOLS, are estimated to check the robustness of the results.

The causality relationship among the studied variables is checked by using the ECM-Granger causality in the first essay.

To investigate the marginal willingness to pay (MWTP) for EVs and the relative importance (RI) of defined attributes in adapting EVs, the MLX is estimated. To check the effectiveness of incentive policies in the penetration rate of EVs the market simulation is applied. To consider the heterogeneity among consumers the LCM is estimated. However, to reduce the latent factors of the psychological character of participants to be included in the LCM, the explanatory factor analysis (EFA) based on polychoric correlation is employed in the second essay.

To identify and rank the barriers to the development of renewable energy in Iran and to determine the most suitable renewable energy technologies among solar PV, wind power, and biomass, the AHP is conducted. Furthermore, to check the reliability and robustness of the results of AHP, the dynamic sensitivity analysis is applied in the third essay.

1.6. Thesis outline

The short and long-run environmental impacts of transportation and power sectors in Iran are examined in chapter two. In chapter three, the willingness to pay for EVs in four megacities of Iran is modeled. The main impediments to the development of the most applicable REs are identified and ranked in chapter four. Finally, this research is ended with a summary and conclusion in chapter five. The results of this study could be used by the government and policymakers to formulate the appropriate policy in the transportation and energy sectors to achieve the goals of sustainable development. Thesis outline is depicted in Figure 1.14.

Chapter 1: Overview (A brief explanation of the dissertation)

Chapter 2: Environmental impact of transportation and power sectors in Iran

Objectives:
Analyzing the short and long run linkages amongst power, transportation sector, and environmental degradation in Iran and identifying the causal direction of investigated variables over 1971-2015.

Questions:
- Analyzing the short and long run linkages among, transportation sector, and environmental degradation in Iran
- Identifying the causal direction of investigated variables

Methodology:
- Applying Autoregressive Distributed Lag (ARDL) model and Error Correction Model (ECM) to evaluate the short and long-run relationship amongst investigated variables.
- Employing co-integration regression called FMOLS, CCR, DOLS to check the robustness of the results of ARDL.
- Deploying the ECM-Granger Causality approach to examine the causality direction amongst studied variables.

Chapter 3: Modelling Consumer's Purchasing Intention for Electric Vehicles in Four Megacities of Iran

Objectives:
Estimating the willingness to pay for specific attributes of EVs in four megacities of Iran from mid-June to mid-July of 2019

Questions:
- What are the determinants of willingness to pay for EVs in four megacities of Iran?
- What are the effective government incentive policies to increase the market share of EVs?

Methodology:
- Employing MXL to calculate the MWTP and RI of defined attributes to adaption of EVs.
- Evaluating the impact of infrastructure development and incentive policies on intention to buy Hybrid Electric Vehicles (HEVs) and Battery Electric Vehicles (BEVs) by conducting a market simulation.
- Considering the preference heterogeneity by using LCM.
- Employing the EFA based on Polychoric Correlation to reduce the latent factors of psychological character of participants in the LCM.

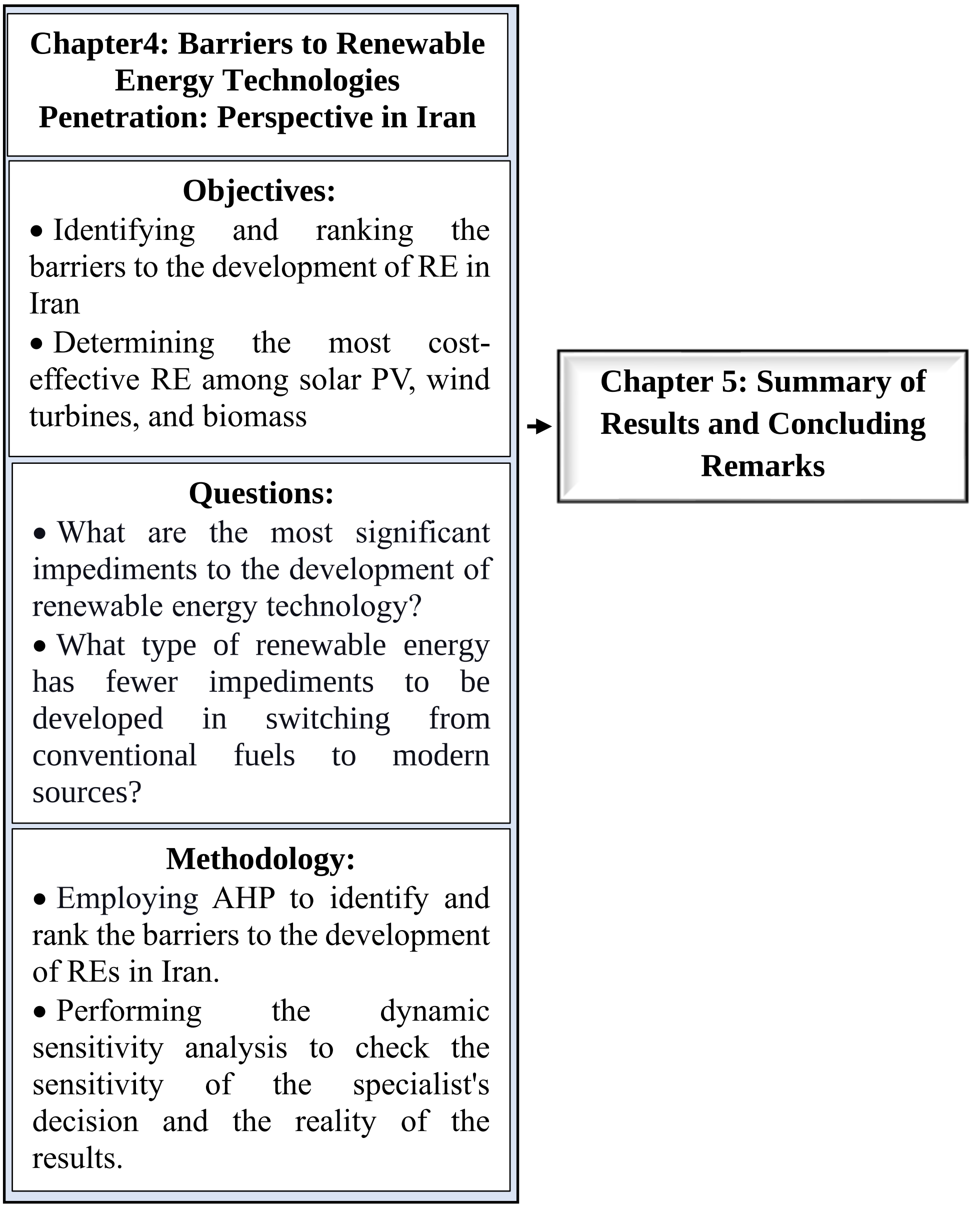


Figure 1.14. Thesis outline

Chapter 2
Environmental Impact of Transportation and Power Sectors

2.1. Introduction

Recently, Greenhouse Gas (GHG) emissions, as the main reason for climate change has emerged as the most serious environmental problem around the world, especially in developing countries (Lin & Zhu, 2019). Indeed, global energy consumption and environmental concerns might be affected by patterns of energy consumption and production of these countries, which originates from their rapid economic development and large population (Sadeghi & Larimian, 2018). It is noteworthy to notice that despite the crucial role of energy in economic development, achieving the goals of sustainable development requires considering the environmental side effects of increasing energy consumption.

As a fast-growing developing country, in 2018, Iran ranked as the largest consumer of energy in the Middle East and North Africa (MENA) (285.7 MTOE) and the world's-ninth largest (Dudley, 2019). Moreover, energy demand in Iran is expected to grow at a rate of approximately 6% per year in the coming decades (Sadeghi & Larimian, 2018). Holding 9% and 12.2% of the total world's affordable oil condensate reserves and gas reserves in 2018, Iran has taken the third and second place in the world (Dudley, 2019). Therefore, it is considered as a fossil fuel-based economy, which utilizes these resources to fulfill the growing domestic energy demand. However, despite the high potential in renewable sources (such as being located on the world's sun belt, enjoying 2800 sunny hours per year, and having average solar insulation (2000 kWh/m^2) (Fadai et al., 2011), while being located on the global geothermal belt), the share of these resources in the energy mix (2%) and electricity generation is low (8% including hydropower). This issue has increased the concerns about environmental degradation (Mohammadnejad et al., 2011). Among consumer sectors, the transportation, followed by electricity and heating production (34.3%), contributes to about 24.9% of carbon dioxide emissions in Iran in 2014 (Mundial, 2018). Therefore, to overcome environmental side effects of utilizing fossil fuels, and to achieve sustainable development goals, Iran placed greater emphasis on environmental issues and is committed to mitigating its GHG emission in 2030 by 4% compared to the Business as Usual (BAU) scenario. Consequently, the government initiated the ambitious plans to extend electric power generation including natural gas-fired, renewable, and nuclear-fired facilities.

This chapter intends to assess the short and long-run relationship between renewable electricity, transportation sector, and CO_2 emissions, as a proxy of environmental degradation, in Iran over 1971-2015. Indeed, this chapter tries to answer the following questions:

i. What are the short and long-run relationships amongst power sector, transportation sector and environmental degradation in Iran?
ii. What are the causal relationships amongst the investigated variables?
iii. What are the most appropriate policies in the energy and transportation sectors to achieve sustainable development goals?

This chapter contributes to the literature in two aspects. To the best of our knowledge, no research has been conducted to evaluate the environmental impact of power and transportation sectors simultaneously not only in Iran but also in other countries or a group of economies. Moreover, there is no research that reviews the short and long-run impacts of renewable electricity and transportation sectors on CO_2 emissions in a country that is having numerous potentials in renewable sources, is suffering from tremendous environmental issues caused by road traffic emissions, while being the leading pollutant. Moreover, this study is trying to check the robustness of the results of ARDL by employing FMOLS, CCR, and DOLS and to investigate the causality direction among variables studied by applying Error Correction Model (ECM)-Granger Causality.

The rest of the chapter is organized as follows. Section-2 describes the theoretical background. Section-3 devotes to the conceptual framework, while Section-4 discuses data and descriptive statistics. Section-5 presents the results and discussion. Limitation and future research explain is the topic of Section-6. The chapter ends up by drawing conclusion and recommendations in Section-7.

2.2. Theoretical background: literature review

The relationship between environmental quality and energy consumption as a production input has been widely investigated since the 1990s. Over the period, numerous studies have been conducted to evaluate this nexus by using different specifications, methodologies, and variables. The related studies could be categorized into two groups (see Appendix A.1).

i. The first group is considered the REs-CO_2 Emissions Nexus in a country or a panel of countries. These studies can be classified into two categories. The first strand, discovered the negative and significant impacts of renewable energy sources on CO_2 emissions (Jebli & Youssef, 2015 for Tunisia; Ben Jebli et al., 2015 for 24 countries in the Sub-Saharan African region; Bölük & Mert, 2015 for Turkey; Dogan & Seker, 2016 for 15 countries in the European Union; Bilgili et al., 2016 for 17 countries of the Organization for Economic Co-operation and Development (OECD); Al-Mulali et al., 2016 for 25 countries of OECD; (Sugiawan & Managi, 2016; for Indonesia; ; Al-Mulali & Ozturk, 2016 for 27 advanced countries; Danish et al., 2017 for Pakistan; Liu et al., 2017 for four countries of the Association of South East Asian Nations (ASEAN); Zoundi, 2017 for 25 African countries; Dong et al., 2017 for Brazil, Russia, India, China and South Africa (BRIC); Dong et al., 2018 for China; Zambrano-Monserrate et al., 2018 for Peru; Sinha & Shahbaz, 2018 for India; Gill et al., 2018 for Malaysia; Y. Chen et al., 2019 for China; Yao et al., 2019 for 17 developing & developed countries, six geo-economic regions; and (Lau et al., 2019) for 18 OECD. The second strand of studies concluded that renewable energy consumption has no impact on CO_2 emissions (Al-Mulali et al., 2015 for Vietnam; Al-Mulali et al., 2016 for Latin America and the Caribbean Countries (LACC); Pata, 2018 for Turkey).

ii. The focus of the second strand is on Energy-CO_2 Emissions Nexus in Iran or a group of countries including Iran. Using different variables and model specification, all investigated studied confirmed the positive impact of energy consumption on

CO_2 emissions (Saboori & Soleymani, 2011; Safdari et al., 2013; Ozcan, 2013; Apergis & Ozturk, 2015; Amadeh & Kafi, 2015; Taghavee et al., 2016; Sarkodie & Strezov, 2019). Al-Mulali et al., 2016, investigated the existence of an environmental Kuznets Curve in seven regions regarding the role of RE. Their obtained outcomes confirmed the negative impact of RE on CO_2 emissions for Central and Eastern Europe (CEE), Western Europe (WE), East Asia and Pacific (EAP), South Asia (SA), and the Americas. However, it cannot affect CO_2 emissions in the case of MENA and Sub-Saharan Africa. Sinha et al., 2017 employed the Generalized Method of Moments (GMM) to determine the impact of different forms of energy consumption on CO_2 emissions in the context of Next -11 countries. Their results supported the negative effect of RE on CO_2 emissions, whereas nonrenewable energy increases it.

From the surveyed literature, the negative impact of switching from conventional fuels (oil, coal, and natural gas) to renewable electricity on CO_2 emissions was confirmed. It means that as a result of utilizing fewer fossil fuels, less CO_2 will be emitted. However, no research has been conducted to evaluate the environmental impact of power and transportation sectors simultaneously neither in Iran nor in other countries or a group of economies. Moreover, there is no research that reviews the short and long-run impacts of renewable electricity and transportation sectors on CO_2 emissions in a country that is having numerous potentials in renewable sources, is suffering from the tremendous environmental issues caused by road traffic emissions, while being the leading pollutant. Therefore, given the negative impact of renewable electricity on environmental degradation, this chapter aims to measure the extent that increasing the share of electricity generated from renewable sources and the number of vehicles on the road can affect CO_2 emissions in Iran. Undoubtedly, knowing this sensitivity (elasticity) can help the government and policymakers to design and structure the appropriate policies regarding two energy-intensive industries (electricity generation and transportation) to pursue green-growth strategies in Iran.

2.3. Methodology

The Eq. (2.1) was estimated to investigate the environmental impact of renewable electricity and transportation sector in Iran.

$$LnPCO_{2_t} = \beta_0 + \beta_1\, Ln\, PY_t + \beta_2\, Ln\, RE_t + \beta_3\, Ln\, NV_t + \beta_4\, Ln\, URB_t + \mu_i \tag{2.1}$$

Conducting this research requires taking six steps (see Figure 2.1).

i. Checking if variables are stationary through conducting unit root tests.
ii. Examining the existence of long-run co-integration amongst studied variables.
iii. Estimating the short-run coefficients by employing the ARDL model. Estimating the long-run relationship amongst the studied variables by re-parametrizing the ARDL model of the co-integrating vector into ECM if the existence of long-run co-integration relationship amongst variables is confirmed in the last step.

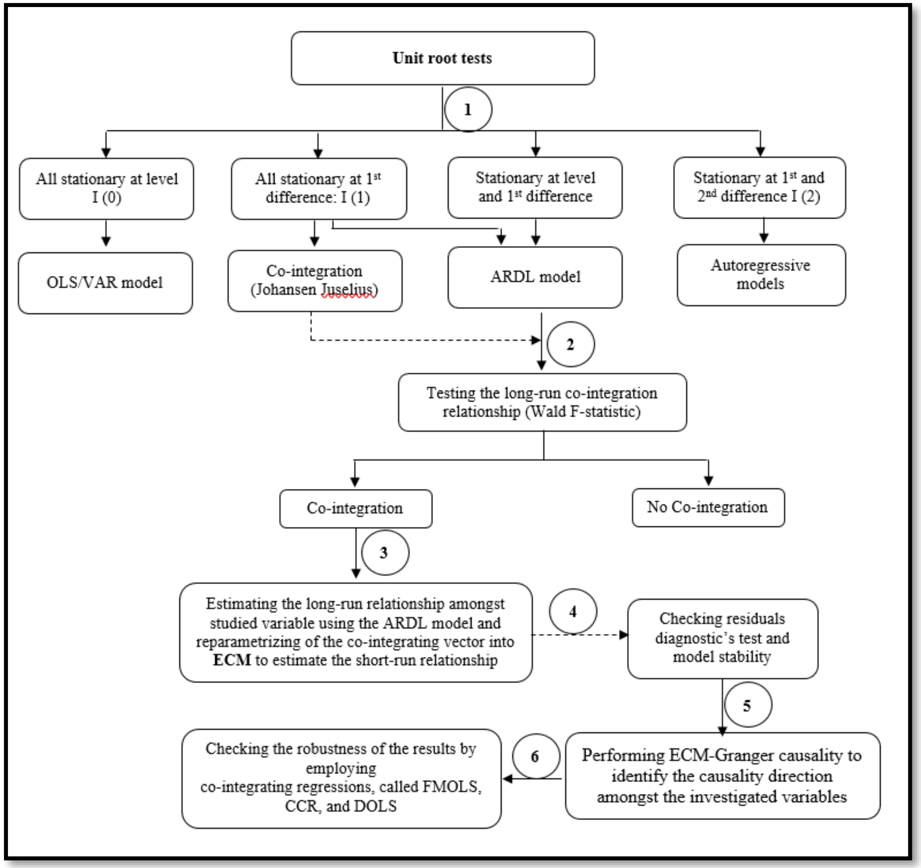


Figure 2.1. Conceptual framework

iv. Checking the residual diagnostic test, including serial correlation; normality; heteroscedasticity; functional form and stability of the model parameters.
v. Checking the robustness of results by performing co-integration regressions, called FMOLS, CCR, and DOLS.
vi. Identifying the causality direction by performing ECM Engel-Granger analysis.

2.3.1. Long-run co-integration and ECM

Followed by Pesaran et al., the ARDL bounds testing was applied (Pesaran et al., 2001). The most significant advantages of this method compared to the Johansen co-integration techniques (Johansen & Juselius, 1990) could be summarized as (1) having better performance in a smaller sample size (Rafindadi & Ozturk, 2017); (2) free of requirements of being integrated of the same order for studied variables (Fatukasi et al., 2015). It indicates that the ARDL approach performs when the dependent variable is I (1) and independent variables are purely I (0) or I (1) or mutually integrated; (3) free from endogeneity problem since the variables considered endogenous (Akalpler & Hove, 2019); (4) extracting adjustment mechanism from the short-run to long-run equilibrium through ECM, which is based on the linear Ordinary Least Square (OLS) transformation (Ahmad & Du, 2017).

Applying the ARDL requires taking two steps:

1. *Determining the existence of a long-run relationship among variables through the Wald F-statistic proposed by* (Pesaran et al., 2001). This test provides lower bound (assumes that all variables are stationary at level) and upper critical bounds (supposes that all variables are stationary at first difference). However, their proposed critical values

were formulated for the large sample size (500-4000) and leads to biased results in the small sample size. To overcome this problem, (Narayan, 2005) has developed a related table for a small sample size (30-80), which was employed in this study. By adding the war dummy variable, The Unconditional Linear Correction Model (ULCM) was estimated to conduct F-bound testing (Eq. (2.2) to Eq. (2.6)).

$$\begin{aligned}\Delta LPCO_{2_t} = \beta_0 &+ \sum_{i=1}^{n_1} \beta_{1i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPY_{t-i} \\ &+ \sum_{i=1}^{n_3} \beta_{3i}\, \Delta RE + \sum_{i=1}^{n_4} \beta_{i4}\, \Delta \mathrm{L}NV_{t-i} \\ &+ \sum_{i=1}^{n_5} \beta_{5i}\, \Delta URB_{t-i} + \delta_0 LPCO_{2t-1} \\ &+ \delta_1 LPY_{t-1} + \delta_2 RE_{t-1} + \delta_3 LNV_{t-1} + \delta_4 URB_{t-1} \\ &+ \mu_t + D_t \end{aligned} \tag{2.2}$$

$$\begin{aligned}\Delta LPY_t = \beta_0 &+ \sum_{i=1}^{n_1} \beta_{1i}\, \Delta LPY_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} \\ &+ \sum_{i=1}^{n_3} \beta_{3i}\, \Delta RE + \sum_{i=1}^{n_4} \beta_{i4} \Delta \mathrm{L}\, NV_{t-i} \\ &+ \sum_{i=1}^{n_5} \beta_{5i}\, \Delta URB_{t-i} + \delta_0 LPY_{t-1} \\ &+ \delta_1 LPCO_{2t-1} + \delta_2 RE_{t-1} + \delta_3 LNV_{t-1} \\ &+ \delta_4 URB_{t-1} + \mu_t + D_t \end{aligned} \tag{2.3}$$

$$\Delta RE_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta RE_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, LPY_{t-i} + \sum_{i=1}^{n_4} \beta_{i4} \Delta \mathrm{L}\, NV_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, URB_{t-i} + \delta_0 RE_{t-1} + \delta_1 LPCO_{2t-1} + \delta_2 LPY_{t-1} + \delta_3 LNV_{t-1} + \delta_4 URB_{t-1} + \mu_t + D_t \tag{2.4}$$

$$\Delta LNV_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta LNV_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, LPY_{t-i} + \sum_{i=1}^{n_4} \beta_{i4} \Delta\, RE_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, URB_{t-i} + \delta_0 LNV_{t-1} + \delta_1 LPCO_{2t-1} + \delta_2 LPY_{t-1} + \delta_3 RE_{t-1} + \delta_4 URB_{t-1} + \mu_t + D_t \tag{2.5}$$

$$\Delta URB_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta URB_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, LPY_{t-i} + \sum_{i=1}^{n_4} \beta_{i4} \Delta\, RE_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, LNV_{t-i} + \delta_0 URB_{t-1} + \delta_1 LCO_{2t-1} + \delta_2 LY_{t-1} + \delta_3 RE_{t-1} + \delta_4 LNV_{t-1} + \mu_t + D_t \tag{2.6}$$

In Equation (2.2), Δ indicates the first differential operator; $\beta_0$is denominated for drift components; μ_t indicates the usual white noise residuals. $\beta_1 - \beta_6$ Show the error correction dynamics. Coefficients δ_0 – δ_4 in the second part exhibit the long-run relationship between analyzed variable, which is assessed through Wald F-statistic. The null hypothesis stands for lack of long-run co-integration amongst investigated variables ($H_0 = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$) against $H_a = \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$ in the equation (2.2). The other equations (Eq. (2.3) through Eq. (2.6)) could be explained in the same way.

Depending on the F-statistics and critical values, three results are possible:

- *Existence of long-run relationship among variables*, if the F-statistics exceeds the upper critical bounds value (the null hypothesis could be rejected)**.**
- *Absence of long-run relationship*, when the F-statistics falls below the lower bound (the null hypothesis could not be rejected).
- *Inclusive results* if the F-statistics places between lower and upper critical bounds. In this case, providing a conclusion needs knowing the order of integration of the underlying regressors. However, the negative value and significance of the ECM could be considered as a way to confirm the long-run relationship among variables (Banerjee et al., 1998).

2. *Estimating the ECM*. If the existence of the co-integration between the analyzed variables is confirmed, appropriate ECM is estimated in the second step. This approach is used to test the speed of adjustment towards long-run equilibrium. The short-run models with a dummy variable is presented through Eq. (2.7) to Eq. (2.11):

$$\Delta LPCO_{2_t} = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPY_{t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, RE + \sum_{i=1}^{n_4} \beta_{i4}\, \Delta \mathrm{L} NV_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, URB_{t-i} + \eta_1 ECT_{t-1} + \mu_t + D_t \quad (2.7)$$

$$\Delta LPY_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta LPY_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, RE + \sum_{i=1}^{n_4} \beta_{i4} \Delta \mathrm{L}\, NV_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, URB_{t-i} + \eta_1 ECT_{t-1} + \mu_t + D_t \quad (2.8)$$

$$\Delta RE_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta RE_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, LPY_{t-i} + \sum_{i=1}^{n_4} \beta_{i4} \Delta \mathrm{L}\, NV_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, URB_{t-i} + \eta_1 ECT_{t-1} + \mu_t + D_t \quad (2.9)$$

$$\Delta LNV_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta LNV_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, LPY_{t-i} + \sum_{i=1}^{n_4} \beta_{i4} \Delta\, RE_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, URB_{t-i} + \eta_1 ECT_{t-1} + \mu_t + D_t \quad (2.10)$$

$$\Delta URB_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i}\, \Delta URB_{t-i} + \sum_{i=1}^{n_2} \beta_{2i}\, \Delta LPCO_{2t-i} + \sum_{i=1}^{n_3} \beta_{3i}\, \Delta\, LPY_{t-i} + \sum_{i=1}^{n_4} \beta_{i4} \Delta\, RE_{t-i} + \sum_{i=1}^{n_5} \beta_{5i}\, \Delta\, LNV_{t-i} + \eta_1 ECT_{t-1} + \mu_t + D_t \tag{2.11}$$

Where η_1 / ECT indicate the error correction parameter/term, respectively. The sign of the coefficient for the lagged error correction term (ECT_{t-1}) must be negative and statistically significant to ensure the convergence of dynamics to long-run equilibrium. The Error Correction term could be explained in a similar pattern for Eq. (2.8) to Eq. (2.11).

2.3.2. Checking the robustness of results

Three co-integration regression (FMOLS, CCR, and DOLS) were employed to check the robustness (sensitivity) of estimated long-run coefficients from ARDL.

A. FMOLS

As the co-integrating linkages lead to the endogeneity problem in the regressor, the FMOLS was developed by (Phillips & Hansen, 1990) to overcome this issue and to illustrate the serial correlation effects. This model adjusts the least squares (Eq. (2.12)).

$$X_t = \widehat{\Gamma_{21}} D_{1t} + \widehat{\Gamma_{21}} D_{1t} + \hat{\epsilon}_t \tag{2.12}$$

It could be obtained directly from difference regression (Eq. (2.13)).

$$\Delta X_t = \widehat{\Gamma_{21}'\Delta}D_{1t} + \widehat{\Gamma_{21}'}\Delta D_{1t} + \hat{\epsilon}_t \tag{2.13}$$

Assuming $\widehat{\Omega}$ and $\widehat{\Lambda}$ show the long-run covariance matrix computed from residuals ($\widehat{\nu_t} = (\hat{\nu}_{1t}, \hat{\nu}_{2t}')^{/}$), the modified data could be written as Eq. (2.14).

$$y_t^* = y_t - \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\widehat{\upsilon}_2 \tag{2.14}$$

An estimated bias correction term could be shown in Eq. (2.15).

$$\lambda_{12}^* = \lambda_{12} - \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\widehat{\Lambda}_{22} \tag{2.15}$$

Therefore, the FMOLS estimator could be presented as Eq. (2.16).

$$\hat{\theta} = \begin{bmatrix}\hat{\beta} \\ \hat{\gamma}_1\end{bmatrix} = \left(\sum\nolimits_{t=1}^{T} \sum_t \sum_t {}' \right)^{-1} \left(\sum\nolimits_{t=1}^{T} Z_t\, y_t^* - T\begin{bmatrix}\hat{\lambda}_{12}^{*\,/} \\ 0\end{bmatrix}\right) \tag{2.16}$$

Where $Z_t = (\acute{X}_t, \acute{D}_t)$. It is noteworthy to mention that construction of long-run covariance matrix estimators ($\widehat{\Omega}$, $\widehat{\Lambda}$) is the key point to estimate FMOLS (Mehmood & Shahid, 2014).

B. CCR

This approach is based on the variable transformation in the co-integrating regression and proposed by (Park, 1992). This method excludes the second-order bias of the OLS estimator. The long-run covariance matrix could be shown in Eq. (2.17).

$$\Omega = \lim_{n\to\infty} \frac{1}{n} E\left(\sum\nolimits_{t=1}^{n} u_t\right)\left(\sum\nolimits_{t=1}^{n} u_t\right)^{/} = \begin{bmatrix}\Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22}\end{bmatrix} \tag{2.17}$$

The Ω matrix could be presented as Eq. (2.18).

$$\Omega = \sum + \Gamma + \acute{\Gamma} \qquad (2.18)$$

Where:

$$\Omega = \lim_{n\to\infty} \frac{1}{n} E(\sum_{t=1}^{n} E(u_t \acute{u_t});$$

$$\Gamma = \lim_{n\to\infty} \frac{1}{n} (\sum_{k=1}^{n-1} \sum_{t=k+1}^{n} E(u_t \acute{u}_{t-k});$$

$$\Lambda = \sum + \Gamma = (\Lambda_1, \Lambda_2) = \begin{bmatrix} \Lambda_{11} & \Lambda_{12} \\ \Lambda_{21} & \Lambda_{22} \end{bmatrix}.$$

Therefore, the transformed series is taken as Eq. (2.19) and Eq. (2.20).

$$y_{2t}^* = y_{2t} - (\sum^{-1} \Lambda_2)^{/} \mu_t \qquad (2.19)$$

$$y_{1t}^* = y_{1t} - (\sum^{-1} \Lambda_2 \beta + (0, \Omega_{12}\Omega_{22}^{-1})^{/})^{/} \mu_t \qquad (2.20)$$

Ultimately, the canonical co-integration regression could be expressed as Eq. (2.21)

$$y_{1t}^* = \acute{\beta} y_{2t}^* + \mu_{1t}^* \qquad (2.21)$$

Where:

$$y_{1t}^* = \mu_{1t} - \Omega_{12}\Omega_{22}^{-1}\mu_{2t} \qquad (2.22)$$

Transforming variables removes the endogeneity problem caused by the long-run correlation between y_{1t} and y_{2t} asymptotically. Consequently, the OLS estimator of Eq. (2.22) indicates the Maximum Likelihood (ML) estimator.

C. DOLS

This method is introduced by (Saikkonen, 1992) and (Stock & Watson, 1993). The co-integrating equation error term resulting from this model is orthogonal to the entire history of the stochastic regressor innovations since it includes augmenting the co-integrating regression with lags and leads (Eq. (2.23)).

$$y_t = \acute{X}_t \beta + \acute{D}_{1t} \gamma_1 + \sum_{j=-q}^{r} \Delta \acute{X}_{t+j} \delta + \nu_{1t} \tag{2.23}$$

By adding q lags and r leads of the differenced regressors, the long-run correlation between ν_{1t} and ν_{2t} is eliminated. Consequently, the result of estimating θ = (β', γ')' using the least-square estimator is equivalent to the asymptotic distribution obtained from FMOLS and CCR.

Briefly, the most impressive advantages of these co-integration regressions could be listed as being free from the endogeneity issue, serial correlation, and small sample size bias (Ahmad & Du, 2017).

2.3.3. The ECM-Granger causality approach

To determine the causality direction amongst the studied variables, the ECM-Granger causality was employed Eq. (2.24) (Bekhet & Othman, 2018) and (Dong et al., 2018).

$$
\begin{bmatrix}\Delta L(CO_2)_t\\ \Delta LY_t\\ \Delta URB_t\\ \Delta RE_t\\ \Delta LNV\end{bmatrix}=\begin{bmatrix}\alpha_1\\ \alpha_2\\ \alpha_3\\ \alpha_4\\ \alpha_5\end{bmatrix}
+\begin{bmatrix}\beta_{11,1} & \beta_{12,1} & \beta_{13,1} & \beta_{14,1} & \beta_{15,1}\\ \beta_{21,1} & \beta_{22,1} & \beta_{23,1} & \beta_{24,1} & \beta_{25,1}\\ \beta_{31,1} & \beta_{32,1} & \beta_{33,1} & \beta_{34,1} & \beta_{35,1}\\ \beta_{41,1} & \beta_{42,1} & \beta_{43,1} & \beta_{44,1} & \beta_{45,1}\\ \beta_{51,1} & \beta_{52,1} & \beta_{53,1} & \beta_{54,1} & \beta_{55,1}\end{bmatrix}\times\begin{bmatrix}\Delta L(CO_2)_t\\ \Delta LY_t\\ \Delta URB_t\\ \Delta RE_t\\ \Delta LNV\end{bmatrix}
+\sum_{i=1}^{p-1}\begin{bmatrix}\delta_{11,i} & \delta_{12,i} & \delta_{13,i} & \delta_{14,i} & \delta_{15,i}\\ \delta_{21,i} & \delta_{22,i} & \delta_{23,i} & \delta_{24,i} & \delta_{25,i}\\ \delta_{31,i} & \delta_{32,i} & \delta_{33,i} & \delta_{34,i} & \delta_{35,i}\\ \delta_{41,i} & \delta_{42,i} & \delta_{43,i} & \delta_{44,i} & \delta_{45,i}\\ \delta_{51,i} & \delta_{52,i} & \delta_{53,i} & \delta_{54,i} & \delta_{55,i}\end{bmatrix}\begin{bmatrix}\Delta L(CO_2)_t\\ \Delta LY_t\\ \Delta URB_t\\ \Delta RE_t\\ \Delta LNV\end{bmatrix}
+\begin{bmatrix}\eta_1\\ \eta_2\\ \eta_3\\ \eta_4\\ \eta_5\end{bmatrix}(ECT_{t-1})+\begin{bmatrix}\mu_{1t}\\ \mu_{2t}\\ \mu_{3t}\\ \mu_{4t}\\ \mu_{5t}\end{bmatrix} \tag{2.24}
$$

Where Δ is first differential operator; α is intercept; the matrices of β and δ imply the long and short-run coefficients, respectively. μ_t Indicates error terms, which are independent and normally distributed, and i denotes the maximum lag length of the analyzed variable. The short and long run causality relationship could be obtained as follows:

1. Short-run (weak Granger causality): evaluating the significance of the first difference of the explanatory variables via F-statistic or Wald- test.
2. Long-run: analyzing the significance of the Error Term coefficient via t- statistic or conducting Wald-test on the lagged ECT.

2.4. Data and descriptive statistics

The environmental impact of renewable electricity and transportation sectors was investigated by using yearly data over1971-2015. PY was the per capita real GDP (constant 2010 US$), followed by Hdom, (2019), PCO_2 was the per capita emissions of carbon dioxide caused by solid, liquid, and gas fuels consumption, measured in metric tons. RE indicated a share of renewable sources (including hydroelectricity, solar, wind, biofuels, biomass, and waste) in electricity generation, which measured in kWh. NV showed the number of vehicles on the road (produced and imported). URB presented urbanization, which measures as the share of urban population in the total population. u showed the residual term. Except for RE and URB, the analyzed variables were converted to the natural logarithm form: (1) to reduce the data variability, (2) to avoid heteroscedasticity problem in the error terms (Y. Chen et al., 2019), and (3) To interpret the obtained coefficients as the elasticity of CO_2 to the independent variables (Jebli & Youssef, 2015) and (Dogan & Seker, 2016). The data on URB and PY were taken from (Mundial, 2018), while the data on RE and PCO_2 were retrieved from the U.S. Energy Information Administration (eia); finally, the data on NV was taken from the Bureau of Autos and Power-train Industries, the Ministry of Industry, Mine, and Trade of Iran (MOIMT). The descriptive statistics were shown in Table 2.1.

Table 2.1. Descriptive statistic

	$LPCO_2$	LPY	RE	URB	LNV
Mean	-5.34	8.64	13.65	58.70	12.37
Median	-5.40	8.59	10.30	58.50	12.24
Maximum	-4.79	9.24	36.90	73.40	14.34
Minimum	-5.88	8.20	2.40	42.10	10.10
Std. Dev.	0.33	0.27	8.94	9.34	1.19
Skewness	0.23	0.65	0.77	-0.08	0.13
Kurtosis	1.75	2.55	2.65	1.80	1.94
Jarque-Bera*	3.31	3.53	4.69	2.74	2.23
Probability	0.19	0.17	0.10	0.25	0.33
Sum	-240.24	388.59	614.40	2641.70	556.68
Sum Sq. Dev.	4.65	3.19	3519.35	3838.02	62.66

*. The null hypothesis refers to normality

as displayed in Table 2.1, the highest mean and standard deviation belonged to urbanization. Accordingly, the lowest mean and standard deviation was related to per capita carbon dioxide emissions and real per capita GDP, respectively. The log-normal distribution of all variables was supported by the Jarque-Bera test.

2.5. Results and discussion

Checking the stationarity of the variables is necessary to avoid the problem of spurious regression (Pata, 2018). Although Augmented Dicky Fuller (ADF) and Philips Perron (PP) are the most common criteria amongst conventional unit root tests, which have been used widely in the literature, they are not robust enough in small samples (Maslyuk & Dharmaratna, 2020). Therefore in this study, KPSS test (Kwiatkowski et al., 1992) was performed (Table 2.2).

Table 2.2. The Unit root test (5% significant level)

Variable	KPSS		Stationary order
	Trend &intercept	Intercept	
$LPCO_2$	0.171		-
LPY		0.241	I (0)
LNV	0.166		
RE	0.210		
URB	0.132		I (0)
$\Delta LPCO_2$	0.087		I (1)
ΔLNV	0.083		I (1)
ΔRE	0.037		I (1)

*. The critical value at 5% level of significant included trend and intercept equals to 0.146 and with only intercept is 0.463.

As can be seen in Table 2.2, the prerequisite of ARDL is satisfied, meaning that the dependent variable is stationary at the first difference (I (1)) and explanatory variables are mutually integrated of (I (0)) and I (1)). There are several methods to select the lag values such as Akaike information criterion (AIC), the Schwarz information criterion (SIC), the Hannan–Quinn information criteria, Adjusted R-squared. It is noteworthy to notice that the models with the minimum criteria value or the maximum value of the R-squared are chosen as the best model. The selected ARDL model is illustrated in Fig. 2.2.

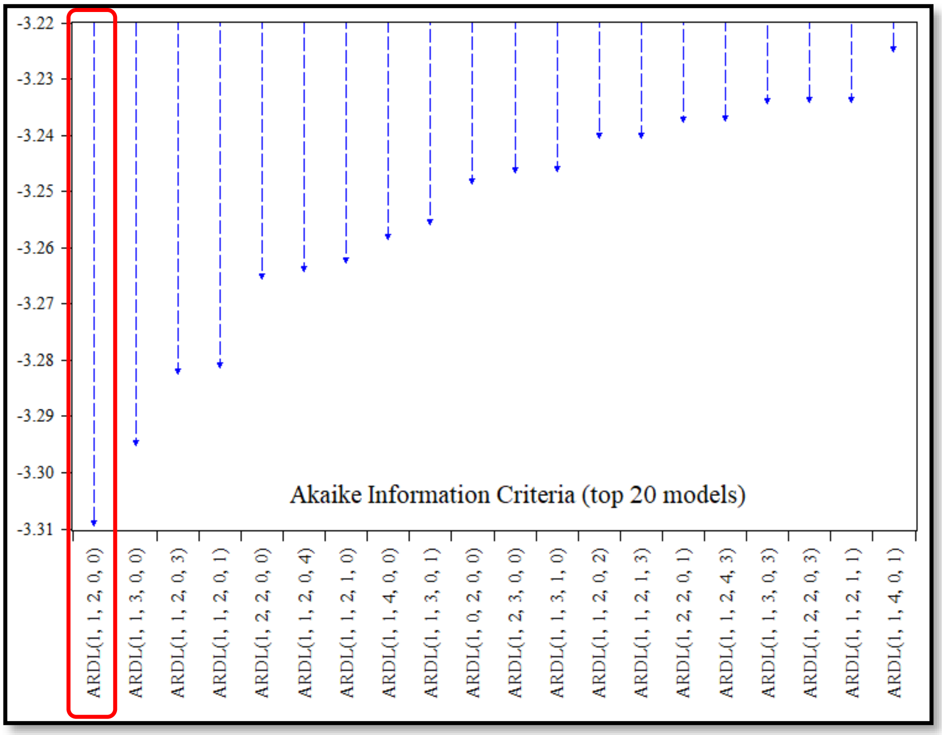


Figure 2.2. ARDL model specification

as shown in Fig. 2.2, the optimal AIC-based ARDL model was (1, 1, 2, 0, 0) with restricted constant and no trend. The maximum lag 1 for the dependent variable (logarithm of per capita emissions of CO_2), and the maximum lags for logarithm of per capita real GDP, Logarithm of the number of vehicles, the share of renewable electricity and urbanization were obtained as 1, 2, 0, and 0, respectively. Accordingly, the optimal lags for other equations were identified. Moreover, to capture the impact of the eight-year Iran/Iraq war on CO_2 emissions, the Dw was added into the model as a dummy variable. The Wald F-statistics was calculated to evaluate the existence of long-run co-integration amongst the variables (Table 2.3).

Table 2.3. ARDL long run form and bounds test

Dependent variable	F-statistic	Co-integration
$F_{LPCO_2}(LPCO_2/LPY, LNV, RE,, URB, D_w)$	10.548***	Yes
$F_{LPY}(LPY/\ LPCO_2, LNV, RE,, URB, D_w)$	9.931***	Yes
$F_{LNV}(LNV/LPCO_2, LPY, RE, URB, D_w)$	4.305**	Yes
$F_{RE}(RE/LPCO_2, LPY, LNV, URB, D_w)$	5.517***	Yes
$F_{URB}(URB/LPCO_2, LPY, LNV, RE, D_w)$	7.008***	Yes

***, **, * significant at 1, 5, and 10%, respectively.
Optimal lag for each equation is selected.
Critical values are collected from (Narayan, 2005).

From Table 2.3, the existence of a long-run co-integration amongst studied variables was confirmed. Therefore, the long-run coefficients were estimated when per capita carbon dioxide is considered as dependent variable (Table 2.4).

Table 2.4. Estimated long-run coefficients

Variable	Coefficient	t-statistic
$\boldsymbol{LPY}$	0.333***	3.375
$\boldsymbol{LNV}$	0.107***	3.591
$\boldsymbol{RE}$	-0.006**	-2.062
$\boldsymbol{URB}$	0.012**	2.396
Constant	-10.132***	-12.842
D_w	-0.176***	-4.656

***, **, * significant at 1, 5, and 10%, respectively.

As exhibited in Table 2.4, logarithm of per capita real GDP was correlated positively and statistically significant with logarithm of per capita emissions of CO_2, ceteris paribus. Indeed, a 10% increase in logarithm of per capita real GDP extended logarithm of per capita emissions of CO_2 by 3.3% if other things kept unchanged. It indicated that environmental degradation is progressing and would remain growing in the future as Iran persists in pursuing a high economic growth strategy. This result is aligned with (Safdari et al., 2013), (Taghavee et al., 2016), and (Amadeh & Kafi, 2015). Moreover, RE was negatively correlated with logarithm of per capita emissions of CO_2 in long-run. The coefficient of this variable showed that switching form fossil fuels to renewable electricity by 10% decreased the logarithm of per capita emissions of CO_2 by 0.06% if other things remained the same. This finding was accompanied by the results of most recently published papers (Table A.1 in appendix A). Furthermore, logarithm of per capita emissions of CO_2 is affected positively by the logarithm of the number of vehicles. Indeed, logarithm of per capita emissions of CO_2 increased by 1% because of a 10% growth in Logarithm of the number of vehicles, ceteris paribus. It was not surprising since:

1. The number of vehicles on the road has increased from 126,664 in 1996 to 1,028,336 in 2015.
2. they are powered by gasoline and diesel (Eskafi, 2016);
3. they operated beyond their standard life cycle (Zarifi et al., 2013);
4. Over 1996 to 2015, the average gasoline and diesel consumption of transportation sector has increased by 146% (from 32.9 to 80 million liters per day) and 127% (from 33.4 to 75 million liters per day), respectively (Mousavi & Ghavidel, 2019);
5. It accounted for 24% of CO_2 emissions related to fossil fuel combustion in 2019.

Urbanization contributed to logarithm of per capita emissions of CO_2 positively, where a 10% increase in the portion of people in the urban area resulted in a 1% increase logarithm of per capita emissions of CO_2 in the long run. This finding was consistent with the results of

(Ozturk & Al-Mulali, 2015), (Taghavee et al., 2016), (Al-Mulali & Ozturk, 2016), and (Pata, 2018). The result demonstrated that the dummy variable lessened the environmental side effects, which could be attributed to the low level of output over the war period. The estimated short-run coefficients are presented in the Table2.5.

Table 2.5. Estimated short-run coefficients

($LPCO_2$ as dependent variable)

Variable	Coefficient	t-statistic
$\boldsymbol{D(LPY)}$	0.507^{***}	6.166
$\boldsymbol{D(LNV)}$	0.033	1.597
$\boldsymbol{D(LNV(-1))}$	-0.094^{***}	-4.123
$\boldsymbol{DW}$	-0.176^{***}	-6.884
CoinEq (-1)	-0.775^{***}	-8.536

***, **, * significant at 1, 5, and 10%, respectively.

Table 2.5 supported the effect of logarithm of per capita real GDP on logarithm of per capita emissions of CO_2 in the short run. Indeed, a 10% increase in real per capita GDP degrades the environment by 5%, ceteris paribus. The error correction term was negative and statistically significant. The coefficient of lagged ECM (−0.78), showed that 78% of the disequilibrium of logarithm of per capita emissions of CO_2 of the shock of the previous year would be adjusted back to its long-run equilibrium in the current year. Indeed, reaching full convergence to the equilibrium needs 1.4 years. To check the perfectness of the model, the residuals diagnostic tests were employed (Table 2.6).

Table 2.6. Diagnostic test results

Diagnostic test	Statistic (p-value)
Serial correlation (Breusch-Godfrey)	0.444 (0.645)
Heteroscedasticity (ARCH)	0.688 (0.411)
Functional form (Ramsey REST)	0.454 (0.505)

B-G null is no serial correlation.
ARCH null is no heteroscedasticity.
Ramsey RESET null is appropriate functional form specification.
P-value are shown in the parentheses.

From Table 2.6, there was no evidence of serial correlation and heteroscedasticity. The "Ramsey Regression Equation Specification Error Test (RESET) test" supported the well-specified functional form for the short-run model. Furthermore, to check the stability of the co-integration parameters, the "Cumulative Sum of Recursive Residuals" (CUSUM) test and the "Cumulative Sum of Recursive Residuals of Square" (CUSUMSQ) tests were implemented. this test is based on the recursive regression (Figures 2.3 and 2.4).

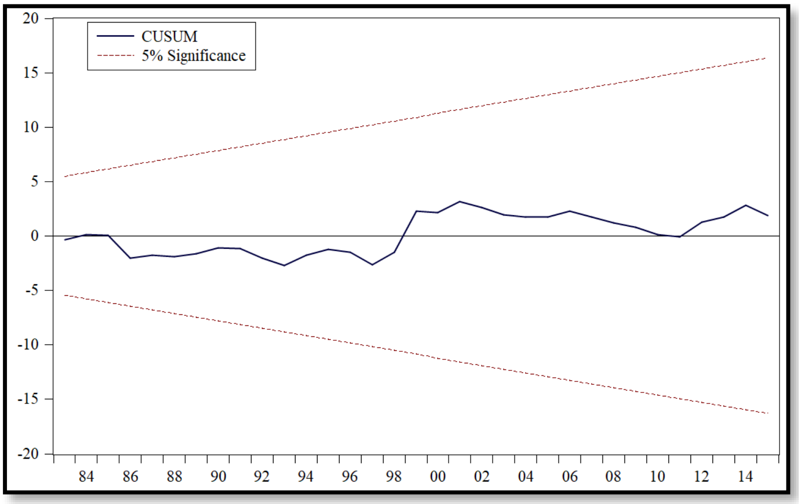


Figure 2.3. The Plot of the Cumulative Sum of the Recursive Residuals

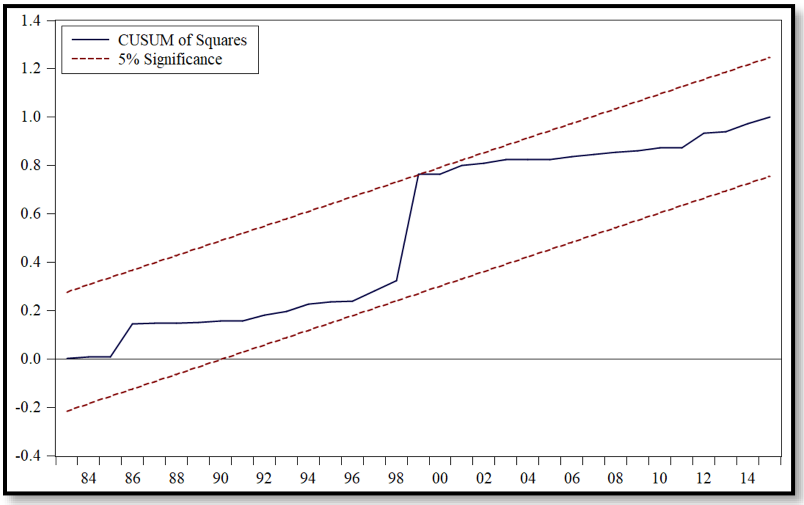


Figure 2.4. The Plot of the Cumulative Sum of the Recursive Residuals Square

The results remained within the critical bounds, which supported the stability of the parameters over time. It means that the model with logarithm of per capita emissions of CO_2 as a dependent variable could be used to formulate appropriate energy policy.

To identify the short and long run causal relationship amongst investigated variable, the ECM-Granger causality was applied (Table 2.7).

Table 2.7. The Engle- Granger causality results based on ECM

Dependent variable: $LPCO_{2t}$						
Variable	Short run coefficient	F-statistics	ECM_{t-1} t-statistic	Long run coefficient	Causality: Short run	Causality: Long run
LPY	0.507***	10.548***	-0.775***	0.333**	$LPY \rightarrow LPCO_2$	$LPY \rightarrow LPCO_2$
RE				-0.006*		$RE \rightarrow LPCO_2$
LNV				0.107***		$LNV \rightarrow LPCO_2$
URB				0.012*		$URB \rightarrow LPCO_2$
Dependent variable: LPY_t						
RE	0.005**	9.931***	-0.628***	0.031***	$RE \rightarrow LPY$	$RE \rightarrow LPY$
LNV				0.098***		$LNV \rightarrow LPY$
Dependent variable: RE_t						
LPY		7.705***	-0.72**	17.76**		$LPY \rightarrow RE$
Dependent variable: LNV_t						
LPY	3.319***	3.849**	-0.424**	2.821***	$LPY \rightarrow LNV$	$LPY \rightarrow LNV$

To gain a better understanding, the long and short-run causal relationship amongst studied variables were depicted in Figures 2.5 and 2.6, respectively.

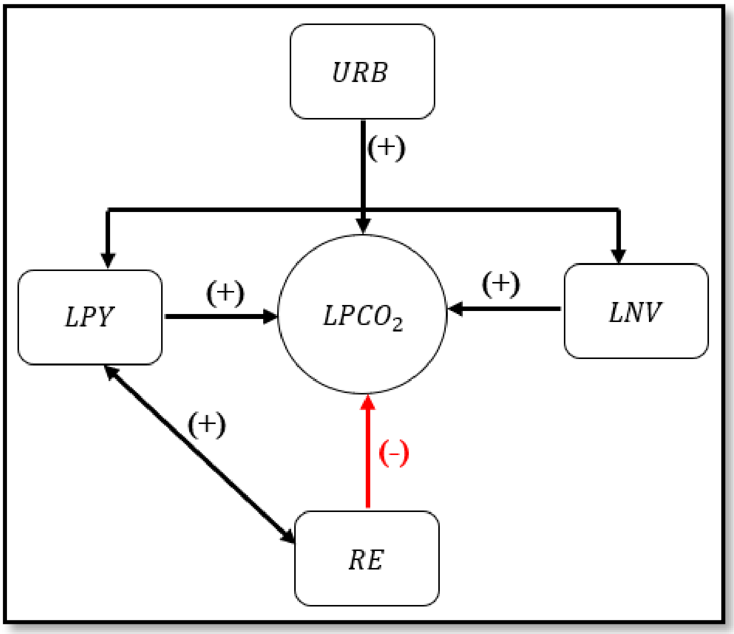


Figure2.5. Long run- causality graph

As depicted in Figure 2.5, the causality direction amongst studied variables could be summarized as follows:

1. The positive unidirectional causality is as follows:

- From the LPY to $LPCO_2$. This fact can be explained by this fact that boosting economic growth needs more usage of natural resources and energy, especially fossil fuels, which leads to the release of large amounts of pollutants and environmental degradation.
- From LNV to $LPCO_2$. This result can be described by the increasing number of gasoline-powered-based vehicles, which operate beyond their life cycles.
- From URB to $LPCO_2$. This fact can be explained by population growth and the rapid speed of urbanization and therefore rising economic activities.

2. The positive long-run bidirectional causality between LNV and LPY, and RE and LPY. Indeed, with financial support and investment from governments, investing in RES can be profitable and increase economic growth. Besides, considering the lower environmental impact of costs of extracting, producing, distributing, and consuming RES, which emerges as the cost savings, the overall economic growth will be larger.

3. The one-way negative causal linkage flew from RE to $LPCO_2$. It implied the potential of renewable electricity in controlling CO_2 emissions. In other words, renewable sources are an appropriate means to achieve the goals of sustainable electricity supply and to mitigate the environmental side effects of emissions from conventional fuels simultaneously. Indeed, it acts as a representative of the composition effect, which takes the change in energy production structure toward clean technology in the long-run as a result of more investment in the RES, technology transfer, and technological changes.

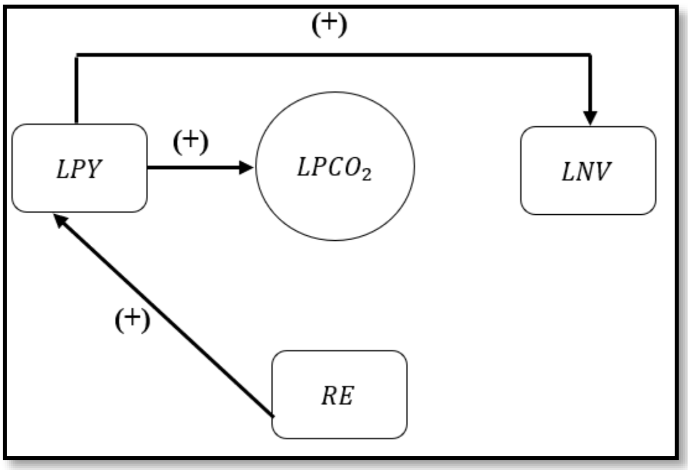


Figure 2.6. Short run- causality graph

As depicted in Figure 2.6, the short-run positive causality ran from LPY to LPCO2, from LPY to LNV, and from RE to LPY.

Finally, to check the robustness of long-run coefficients from the ARDL approach, the results of FMOLS, CCR, and DOLS were summarized in Table 2.8.

Table 2.8. Co-integration regression analysis

Estimation method	FMOLS	CCR	DOLS
LPY	0.485***	0.451***	0.412***
LNV	0.050**	0.059**	0.096**
RE	-0.002	-0.002	-0.008
URB	0.024***	0.231***	0.013*
Constant	-11.522***	-11.275***	-10.713***
Dw	-0.141***	-0.154***	-0.810***
R^2	0.976	0.975	0.987
$\overline{R}^2$	0.973	0.972	0.979
Co-integration test (1)	0.673***	0.425***	0.068***
Normality (2)	0.760***	0.438***	8.309**

(1). Co-integration test has been conducted by Hansen parameter instability in which null hypothesis indicates existence of co-integration in the time series (Hansen, 1992).
(2). the normality test has been checked by the Jarque- Brea test, in which the null hypothesis implies a normal distribution of residuals.
P-value are shown in the parentheses
***, **, * significant at 1, 5, and 10%, respectively.

According to Table 2.8, the results from three co-integration regression were in line with the ARDL results in terms of sign and significance, which verified the perfectness of the initial ARDL model.

2.6. Limitations and future researches

The results of this chapter can provide useful insight and crucial information for the government and policymakers about the impact of electricity generation sources and the number of vehicles on the environment quality to formulate appropriate policies.

However, lack of available data on RES by type was one of the most challenging issues in conducting this research. Having separate data on each type of RES may help the government and policymakers to form the optimal electricity generation mix to reduce environmental degradation.

Furthermore, considering the symmetric/asymmetric impact of renewable electricity and the transportation sector on environmental degradation can be a fascinating topic for future studies. This goal can be achieved by employing other versions of the ARDL co-integration family such as Dynamic ARDL, Nonlinear ARDL, Quantile ARDL, and so on.

2.7. Conclusions and recommendations

As mentioned before, among energy consumer sectors in Iran, electricity and heat producers, followed by the transportation sector accounted for 48% of CO_2 emissions in 2019, which is caused by the dominant share of conventional fuels in the electricity generation mix and the increasing number of vehicles on the road. These vehicles are driven by gasoline or dual fuel (gasoline/CNG) and are operating beyond their standard life cycle.

Overcoming the environmental side effects of burning fossil fuels, particularly in the largest consumer energy sectors, and formulating appropriate policies in these sectors, requires the evaluation of the short-and long-term sensitivity (elasticity) of CO_2 emissions regarding the renewable electricity and the number of vehicles on the road.

From the surveyed literature, no research has been conducted to evaluate the environmental impacts of the transportation sector and renewable energy simultaneously, neither in Iran nor in other countries.

This study was conducted to evaluate the short and long-run impact of renewable electricity and transportation sector on CO_2 emissions in Iran over the period 1971-2015. The annual data on per capita CO_2 emissions as a dependent variable, the share of renewable electricity and the number of vehicles on the road (both produced and imported), as explanatory variables were considered in Iran over the period 1971-2015. Given the importance of the per capita real GDP as the crucial economic variable and the increasing growth of population in Iran and its role in emitting CO_2, as well as urbanization, these variables also were added to the model. Moreover, to capture the impact of war, the war dummy variable was included in the model.

Due to the advantages of the ARDL co-integration bounds testing model over other co-integrating technique (Johansen) model such as good performance for smaller sample size; flexibility in the order of investigated variables (no need for same order for all variables); free from endogeneity problem; ability to extract the adjustment mechanism from short-to long-term equilibrium, this method was employed in this chapter. Since the existence of long-term co-integration was confirmed, the ECM was applied to estimate the short-term coefficients.

Using different diagnostic residual tests such as serial correlation, normality, heterogeneity, appropriateness of functional from of the selected model, and stability of the parameters over the horizon was checked. Considering the consequence of the causal relationship among investigated variables in designing the green-growth strategy, which can control environmental degradation and boost economic growth simultaneously, the ECM-Granger causality was conducted. Finally, three co-integration regressions, called FMOLS, CCR, and DOLS were applied to check the robustness and perfectness of the obtained results from the ARDL model.

The results of unit root tests confirmed the possibility of applying the ARDL model. It means that the CO_2 emissions was identified at the first difference and none of the independent variables were stationary at second difference. The existence of long-run co-integration among investigated variables were confirmed by employing bounds test. The results of long-run estimation verified the negative impact of renewable electricity on environment degradation. Indeed, switching from fossil fuels to renewable electricity by 10% decreases per capita CO_2 emissions by 0.06%, ceteris paribus. Furthermore, the positive impact of per capita real GDP, the number of vehicles on the road, and urbanization on per capita CO_2 emissions was affirmed. Besides, contradicting the output level in the war period lessened the environmental side effects, which could be realized from the dummy variable. The negative and significant coefficient of the error correction showed that full convergence to the long-run equilibrium takes 1.4 years. The residual diagnostic/ sensitivity tests based on FMOLS, CCR, and DOLS verified the perfectness and robustness of the results from the ARDL.

The results of this study provide some policy implications for the government as follows:

1. The positive impact of the number of vehicles on economic growth and environmental degradation, verified by ECM-Granger causality, implies that boosting the economic growth and controlling carbon dioxide emissions simultaneously requires designing and structuring a proper transport policy. Accordingly, the negative, and positive impacts of renewable electricity on CO_2 emissions and economic growth, respectively show that reducing the environmental issues, caused by road traffic emissions, could be realized by *replacing the vehicles powered by Internal Combustion Engines (ICE) with Alternative Fuel Vehicles (as useful technological innovations)*. However, it is noteworthy to mention that achieving this goal requires the generation of electricity needed to drive AFVs from renewable energy. The government and policymakers, the trustee in the supply-side, are scheduled to produce EVs. However, designing and structuring the appropriate policy for EV market requires considering the supply and demand-side simultaneously. The consumer's willingness to pay for EVs in four megacities of Iran is modeled in chapter three.

2. The positive impact of renewable electricity on economic growth and environment quality, showed *diversification of energy/electricity mix* (*increasing the share of renewable sources*) is a proper energy policy to achieve the sustainable development goals. However, the low share of Res supported the existence of numerous impediments, which slowed down the speed of its development. These barriers are explained in details in chapter four.

Chapter 3

Modelling Consumer's Purchasing Intention for Electric Vehicles in Four Megacities of Iran

3.1. Introduction

Based on the report prepared by the International Energy Agency, the transport sector is responsible for 24% of direct CO_2 emissions from fuel combustion (*International Energy Agency*, 2020) Indeed, a broad spectrum of sustainability concerns such as environmental hazards, high oil dependency, global warming (climate change), etc. are caused by the road transport sector, which is powered by conventional fuels (Liao et al., 2019a). Accordingly, designing proper emissions reduction plans in this sector plays a crucial role in achieving the Kyoto Protocol goals to reduce the global average temperature below 2°C. Therefore, along with developing renewable energy sources over time, the electrification of vehicles has drawn the attention of government and policymakers (1) to decrease dependence on fossil fuels in the transportation sector and (2) to lessen the pollution emitted by this sector (S. C. Ma et al., 2019) and (Globisch et al., 2019). The contribution of Electric Vehicles (EVs) come not only from the use of more efficient engines than conventional vehicles but also from the possibility of using renewable energy to charge electric batteries (Oliveira et al., 2019). Consequently, the substitution of fossil fuel-based cars with clean sources-based vehicles has been considered as a useful technological innovation in designing pro-environmental policy in the transportation sector (Liao et al., 2019b and Simsekoglu & Nayum, 2019).

Like other countries around the world, transportation and electricity sectors in Iran are leading sources of carbon dioxide emissions and have a significant contribution to climate change, which is caused by their high dependence on carbon-based fuels and inefficient technologies. Therefore, to improve the air quality and to enhance fuel efficiency, the government introduced Bus Rapid Transit (BRT) in 2008, which has been expanded to seven lines by 2017. Furthermore, the government formulated requirements about the installment of Diesel Particulate Filter (DPF) on all new High-Duty Vehicles (HDVs) powered by diesel in 2016 (V. Hosseini & Shahbazi, 2016). It is noteworthy to notice that the Ministry of Industry, Mine, and Trade of Iran (MIMT), as a trustee and shareholder in the auto industry, has not taken adequate measures to produce EVs. Despite studies carried out by Iran Khodro Company (IKCO) and SIPA Group, as the dominant car manufacturers, these vehicles have not been commercialized and have not penetrated market yet and its appropriate penetration is essential. Hence, the misrecognition of the consumer's dynamics toward sustainable and decarbonized transport (Noel et al., 2019a) by the supply side (the EVs manufacturers and policy-makers), decreases the acceptance of EVs. According to (Egbue & Long, 2012a) and (Rezvani et al., 2015), the cost is among the most important barriers in accepting EVs, therefore, evaluating the willingness to pay for specific attributes of EVs and investigating individual preferences is essential in identifying the barriers in accepting EVs and designing appropriate policy.

Therefore, this chapter intends to answer the following questions:

i. What are the determinants of willingness to pay for EVs in four megacities of Iran?

ii. What are the effective government incentive policies to increase the market share of EVs?

This chapter contributed to the surveyed literature in three ways: 1. No research has been conducted to investigate the WTP for EVs for country with abundant fossil fuel reservoirs and potentials in renewable sources simultaneously, with dominant conventional- powered transport sector, and with high intention to diversify the energy mix. 2. Considering psychological characteristics. 3. Employing the polychoric correlation matrix rather than the Pearson correlation to identify the optimal factors in the psychological part in explanatory factor analysis, since categorical variables (5-points Likert scale) have been used.

The rest of this chapter is structured as follows. Section-2 describes the basic concepts including modeling techniques. Section-3 presents influential factors on willingness to pay for EVs. Section 4- defines sample characteristics. Section-5 reports the used methodologies, while the section-6 devotes to the results and discussion. Limitation and future research demonstrate in the Section-7. Finally, the chapter ends by drawing conclusions and exposing the recommendations in Section-8.

3.2. Basic concepts

3.2.1. Electric vehicles' technology

Conventional Vehicles are characterized by 1. Having Internal Combustion Engines (ICEs); 2. Being powered by petroleum; 3. Having high contribution in emitting greenhouse gas; 4. Performing inefficiently. In contrast to conventional vehicles, AFVs work with at least one alternative fuel to petroleum and diesel such as biofuels (ethanol, biogas) and electricity. In turn, EVs are vehicles in which different technology such as HEVs, Plug-in Hybrid Electric Vehicle (PHEVs), BEVs, Fuel Cell Eclectic Vehicles (FCEVs), and Range Extended Electric Vehicles (REEVs) is used (Rezvani et al., 2015). The most significant features of these vehicles are summarized in Table 3.1.

Table 3.1. Types of EVs

Types of EVs	Driven forces	Description
BEVs	On-board battery	
HEVs	ICE and an electric motor	Mainly driven by ICE and electric motor assists ICE in acceleration. The battery for powering electric motor charged internally by ICE.
PHEVs	ICE and an electric motor	The battery can be charged externally
REEVs	ICE and an electric motor	ICE works as an electricity generator
FCEVs		Powered by electricity, which is generated by a fuel cell stack.

Source: Author based on (Q. Zhang et al., 2018).

The most significant advantages of EVs could be summarized as 1. lower operating cost (Dijk et al., 2013) and (Simsekoglu & Nayum, 2019), 2. higher energy efficiency, energy security, more economical driving cost/km, less noise and air pollution (Grauers et al., 2013), 3.

Environmental gains, 4. economic benefits due to having purchase incentives (Simsekoglu & Nayum, 2019 and Wang et al., 2019) and 5. petroleum saving (Wang et al., 2019). However, despite enormous endeavors on the policy-makers and manufacturers' side to encourage personal transport to utilize EVs, car buyers are reluctant toward environment-friendly, more sustainable, and more efficient alternatives to ICEVs (Eskafi, 2016). It could be explained partly by the higher purchase price, lack of awareness about innovative technology, and so on, which is explained in detail in the literature review.

3.2.2. Modeling techniques: an overview

Given that EVs are the newly introduced engine technologies, the Stated Preference (SP) data have predominated over the Revealed Preference data (RP) in many studies. Indeed, it is an appropriate method to estimate the performance of non-market goods (the products or services that have not yet penetrated/ or have newly been introduced to the market). Non-market goods valuation methods should be used in this case. Amongst these methods, the Contingent Valuation (CV) and Choice Experiment (CE) are the most popular. The former asks the respondents directly about their WTP, while the latter drives the respondent's willingness to pay by asking them to assess value trade-offs amongst attributes (J. H. Kim et al., 2019).

CE has several advantages over CV, which could be summarized as follows:

- Calculate mean WTP and MWTP (implicit price) for different attributes and provide more information (Hoyos, 2010);
- Allow obtaining a more profound perception of the trade-offs between different attributes (Mahieu et al., 2014);
- Suitability to evaluate the multi-attribute goods such as EV (J. H. Kim et al., 2019).

Firstly, the basic Multinomial Logit (MNL) model is used widely in most studies (McFadden, 1973). But this model supposes Independence from Irrelevant Alternatives (IIAs) that do not exist in most cases. Therefore, to ease this restriction, the Nested Logit (NL) model has been used in some studies (Train, 2003). In this model, alternatives place into several nests based on the correlation among them. The similar alternatives arranged in a nest and compete more with each other than with alternatives in other nests. However, these two models assume the same preferences for all consumers, which is not realistic. To overcome this problem, the MXL model or the Random Parameter Logit (RPL) has been developed and became more popular from 2010 (Liao et al., 2017). This model enhances the MNL by relaxing the assumption of IIAs (J. H. Kim et al., 2019). Moreover, it is a useful approach to consider the heterogeneity in unobserved factors through measuring individual deviation from the mean of choice behavior, called the non-zero random term (Wang et al., 2017). In other words, MXL can capture the taste heterogeneity across individuals (Nazari, Mohammadian, et al., 2019). Three possible methods to identify the heterogeneity source could be listed as follows:

1. Traditional Segmentation (TS): In this method, Alternative-Specific Constant (ASC) and measured Individual-Specific Variables (ISV) were included in the utility function to check their significance statistically. However, this method has a limited theoretical base, and results are evaluated based on p-values.

2. Hybrid Choice Model (HCM). It is a modern method to consider heterogeneity amongst individuals and to identify the influential latent variable (Ben-Akiva et al., 2002). The latent variables were incorporated into the model, measured by various indicators, and affected by exogenous variables such as socio-economic (Chorus & Kroesen, 2014).

3. LCM, assumes that consumers could be classified into several classes based on different preferences (Boxall & Adamowicz, 2002). Being a member of each class depends on individual characteristics.

3.3. Influential factors on willingness to pay for EVs: literature review

Macro (time series and diffusion models), micro (economic preference models), and hybrid (attitudinal models) are among three general methodologies to investigate car choice and car use. Based on delivered literature, influential factors on consumer's willingness to pay for EVs could be categorized into three groups, named situational, demographic, and psychological (see Figure 3.1).

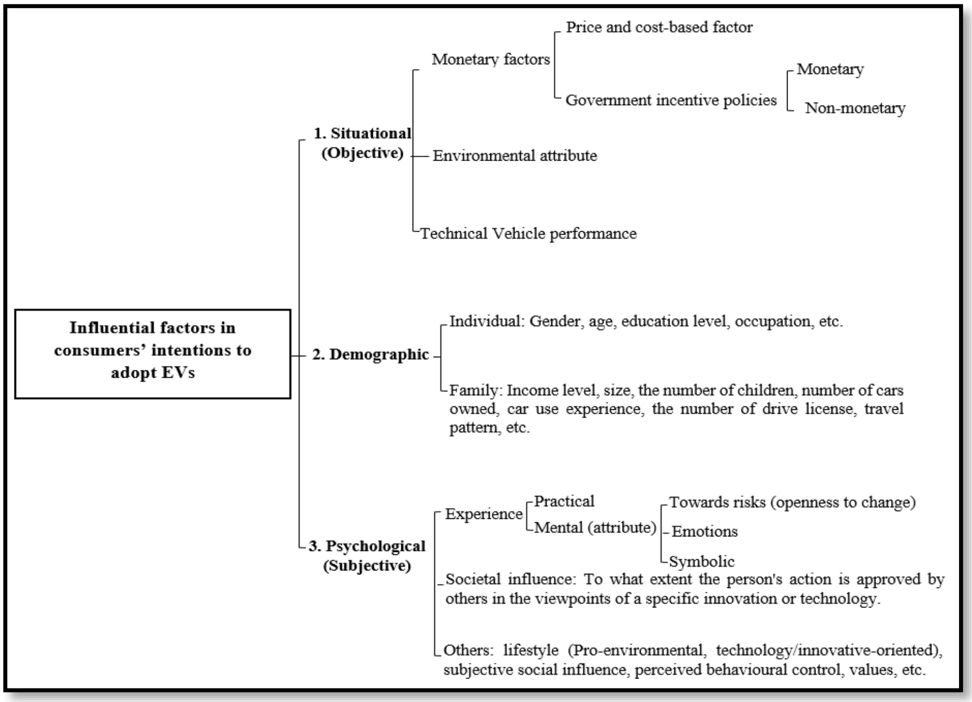


Figure 3.1. Influential factors in consumers' willingness to pay for EV

3.3.1. Situational (objective)

BEVs have some performance features such as refueling time and driving range, which makes them different from conventional fuel vehicles and EVs. Besides, they are different in some objective factors such as consumption of energy, reduction in GHG emissions, and benefit from incentive policies (Li et al., 2017). This attribute could be categorized into three groups called *monetary factors* (cost/price, government incentive policies); *environmental attitude*; *technical vehicle performance*, which would be explained in detail in the next sections.

3.3.1.1. Monetary factors

The monetary factors refer to monetary attributes. The purchase price was incorporated as an influential factor in intention toward EVs. In all previous studies, the negative and high significance effect of this attribute was confirmed (Table 3.1.).

Operating costs were found as another important monetary attribute, which has appeared under different specifications. Some of the most frequently used terms for this attribute could be listed as 1. cost per distance for example per mile, per km, or per 100 km (Hackbarth & Madlener, 2016); 2. Cost per period (year, month, and week); 3. Cost per gallon or gallon equivalent; 4. Cost of electricity relative to gas. As was expected, this attribute is associated with the consumer's decision-making negatively. Although some studies considered battery cost indirectly by incorporating it in the purchase price of EVs, some other studies viewed it as an individual attribute. Moreover, (Lin & Wu, 2018) analyzed the impact of fuel cost and revealed the negative and significant effect of this attribute on the willingness to pay. Furthermore, the *higher initial costs compared* ***to*** the conventional fuel-based vehicle, *battery replacement cost***,** *uncertain fuel cost-saving, the uncertain total cost of ownership over the vehicle life* are amongst cost-related attributes. These factors could be regarded as one of the most important limitations to adopting EVs (Wang et al., 2019).

The *government incentive policies* include various policy instruments to improve the market share of EVs. From the surveyed literature, the incentive policies could be categorized into two different groups (Wang et al., 2019), (S.-C. Ma et al., 2019), (Santos & Davies, 2019), (Shafiei et al., 2018), (Wang et al., 2017), (Wang et al., 2017), (Mersky et al., 2016).

1. Monetary: (subsidies on vehicles and fuels; reduced ferry rates; exemption (registration tax, road tolls; purchase tax; vehicle and the vessel tax; value-added tax; parking fee; insurance fee; public charging).

2. Non-monetary: purchase restriction rescission, driving restriction rescission, access to bus lanes, cruise range, public EV charging station construction.

3.3.1.2. Environmental attitude

Being independent of oil and having the ability to control emissions pollution is amongst the advantages of BEVs, which could be a reason for promoting these vehicles worldwide (Li et al., 2017). Therefore, besides the energy conservation characteristics of BEVs, the environmental benefits (protection) have been considered as a driving factor to increase the adoption rate of EVs (Prakash et al., 2014), (Peters & Dütschke, 2014). However, (Graham-Rowe et al., 2012) pointed out that environmental protection is not the main concern of consumers in the purchasing process of BEVs. Moreover, due to creating huge amounts of pollution in batteries and electricity generation process and pollution from discarded batteries, some consumers do not count the capability of these vehicles in protecting the environment (Axsen et al., 2012). However, through implementing carbon-labels, using recycled batteries, and generating electricity from green sources, the adoption rate of EVs could be increased.

3.3.1.3. Technical vehicle features

Technical vehicle characteristics are other attributes, which affect the consumer's willingness to pay for the car and therefore are included in the choice experiments of nearly all examined studies. The most significant technical/functional attributes of EVs, which frequently appeared in most investigated studies were reported as follows. The *driving range* was amongst the most serious obstacles of EVs, which limited its adoption rate (Simsekoglu & Nayum, 2019), (S.-C. Ma et al., 2019), (Liao et al., 2019a), (Yong & Park, 2017a), (Yong & Park, 2017b), (Axsen & Kurani, 2013), (Graham-Rowe et al., 2012), (Power, 2010). Charging-related problems such as the longer time needed to recharge (Simsekoglu & Nayum, 2019), (S.-C. Ma et al., 2019), (Liao et al., 2019a), (Yong & Park, 2017a), (Yong & Park, 2017b), (Graham-Rowe et al., 2012), (Saxton, 2011), and insufficient charging infrastructur*e* (Liao et al., 2019a), (Biresselioglu et al., 2018), (Axsen & Kurani, 2013), (Egbue & Long, 2012b), were another functional obstacles (Simsekoglu & Nayum, 2019), (Liao et al., 2019a), (S.-C. Ma et al., 2019), (Yong & Park, 2017a), (Yong & Park, 2017b), (Graham-Rowe et al., 2012), (Saxton, 2011), (Power, 2010) could be regarded as other influential factors to reduce the adoption rate.

Moreover, uncertainties about EV's performance including 1. safety, size, and style (Egbue & Long, 2012a); 2. engine power and performance (Graham-Rowe et al., 2012), (Egbue & Long, 2012a); 3. vehicle reliability (Egbue & Long, 2012b); 4. Trunk space, top speed (Li, Long, and Chen 2016), (Jensen, Cherchi, and Mabit 2013); 5. perceived accident risk (Simsekoglu & Nayum, 2019); 6. short battery life, and uncertainty about the speed of technological change (Simsekoglu & Nayum, 2019), (Liao et al., 2019a), (Li, Long, and Chen 2016), (Jensen, Cherchi, and Mabit 2013), (Egbue & Long, 2012b); 7. possible vehicle obsolescence (Graham-Rowe et al., 2012) were considered as influential factors on the willingness to pay for EVs.

3.3.2. Demographics

Recently, considering the impact of demographic factors on eco-friendly purchasing habits has drawn the researchers and analyst's attention. Accordingly, numerous researches have been urged to evaluate the effect of these factors on consumer's decision to adopt EVs, concentrating on *individual* and *family* factors. Gender, age, income, occupation, and educational level were amongst the most related individual- demographic factors, which frequently have been investigated in the literature of willingness to pay for EVs (Liao et al., 2019a), (Wang et al., 2019), (J. H. Kim et al., 2019), (Wang et al., 2017)**,** (Hackbarth & Madlener, 2016), (Lin & Wu, 2018), (Mersky et al., 2016), (Li et al., 2020), (Gong et al., 2020), (Qian et al., 2019), (Noel et al., 2019b), (Ito et al., 2019), (Nazari et al., 2018), (Ferguson et al., 2018). Unlike a daily commodity, deciding about purchasing EVs depends on consumer characteristics and their family features as well (Li et al., 2017). The most significant family factors in the literature could be summarized as the number of owned vehicles in the family (Y. Zhang et al., 2011), (Hidrue et al., 2011), (Hackbarth & Madlener, 2013), and (Peters & Dütschke, 2014), the number of driving licenses (Y. Zhang et al., 2011), availability of charging at home or nearby (Hidrue et al., 2011), (Hackbarth & Madlener, 2013), and (Plötz et al., 2014), family size (Prakash et al., 2014), (Plötz et al., 2014), and (Plötz et al., 2014) travel patterns, and so on.

3.3.3. Psychological (subjective)

Deciding on buying EVs not only depends on the objective and demographics factors but also on subjective (psychological) factors as well. These factors can affect the intention to buy EVs both directly or indirectly through mediating the objective factors (Lai et al., 2015). Hence, to gain a better understanding of influential factors on accepting EVs, some of the psychological factors were summarized in the following sections.

3.3.3.1. Experience and perceived behavioral control (PBC)

The experience covers general life experience, education, awareness of related issues, and *practical experience* with a special product (Schulte et al., 2004). In contrast to the practical experience, the mental experience, which is called an attribute, could be considered as a reflection of consumer's negative or positive evaluations of special behaviors or established dislikes or likes (Li et al., 2017). However, some previous studies explained that attribute differs from both cognition and *affective components*, which is named emotion (Van der Pligt et al., 1997), (Duerden & Witt, 2010), (Nameghi & Shadi, 2013). These components reflect both negative attributes (anxiety, shame, and antipathy) and positive ones (passion, approval, and vanity). Moreover, it can help to evaluate the extent that targets or activities fulfill someone else's wants. Besides cognition and emotion, individuals' behavior depends on the supportive role of PBC, which originates from internal and external forces (Ajzen, 2002).

3.3.3.2. Social influence

As people continually change their behavior based on public opinion, it could be concluded that human performance was not only an individual act but also a societal activity. Accordingly, considering the personal behavior in the frame of sociological attitude has drawn scholars' attention, from the 1990s onward (Kollmuss & Agyeman, 2002). This factor measures the importance of accepting individuals' activity (such as selecting unique innovation or technology) by others such as family, neighbors, friends, and so on.

3.3.3.3. Other psychological factors

From investigated literature, there were other influential psychological factors such as lifestyles, values, environmental awareness, and symbols. *Lifestyle* includes demographic- related factors (tangible) and psychological- related aspect of the individual factors (intangible), which originates from the market segmentation theory. This theory is based on the differences between the living standards of individuals. The result of (Axsen et al., 2013) demonstrated that people with technology-oriented and pro-environmental lifestyles are more likely to adopt BEVs. Values can be defined as the used standard to assess and choose specific behavior as well as to evaluate themselves and others. The core criterion to select a vehicle depends on the consumer's values. For instance, consumers with self-centered values decide based on personal benefit, while a consumer with altruistic values considers the vehicle as an environmental issue (Peters & Dütschke, 2014). Environmental concerns cover consumer's awareness about environmental issues and their tendencies to solve the problem or their purpose to contribute individually to the solution (Sang & Bekhet, 2015). Owning the car could be considered as a *symbol* of self-image and social situation. Indeed, to increase the self-recognition and self-evaluation, an individual tends to compare himself or herself with others (family, neighbor, friend, and so on). This fact could be explained in the framework of Social Role Theory (Breakwell, 1993). Some studies confirmed the positive impact of symbols on the consumer’s intention towards EVs (Skippon & Garwood, 2011), (Schuitema et al., 2013), (Noppers et al., 2014).

There are numerous studies to evaluate consumer's preferences toward AFVs, using various search engines such as Science Direct, Google Scholar, Scopus, Springer, the most related studies were listed in 3.2.

Table 3.2. Summary of current studies on influential factors on consumer's intention to EVs

Study	Location	EV type	Model	Influential factors						
				Situational (objective)			demographic	Psychological (subjective)		
				MF	EA	TP		E and PBC	SI	others
(Li et al., 2020)	China	FCEV	MXL	✓	✓	✓	✓			
(Gong et al., 2020)	Australia	EV	MNL, LCM	✓		✓	✓			
(S. C. Ma et al., 2019)	China	BEV, PHEV	MNL, MXL	✓						
(Qian et al., 2019)	China	PV, PHEV, BEV	MXL	✓		✓	✓			
(Wang et al., 2019)	30 countries	BEV, PHEV, FCEV, HEV	MLR	✓	✓	✓	✓			
(Santos & Davies, 2019)	five European countries	EV	Qualitative	✓						
(Liao et al., 2019a)	Netherland	PHEV, BEV	HCM	✓		✓	✓			
(Noel et al., 2019b)	Nordic region	EV, V2G	MXL	✓		✓	✓			
(J. H. Kim et al., 2019)	South Korea	FCEV	MXL	✓	✓	✓	✓			
(Ito et al., 2019)	Japan	SEV, REV	MXL	✓	✓	✓	✓			
(Shafiei et al., 2018)	Iceland	HEV, PHEV, BEV	SMIETS	✓		✓				

Study	Location	EV type	Model	Influential factors						
				Situational (objective)			demographic	Psychological (subjective)		
				MF	EA	TP		E and PBC	SI	others
(Lin & Wu, 2018)	first-tier cities of China	EV	OLR	✓		✓	✓		✓	✓
(Nazari et al., 2018)	The U.S.	HEV, PEV	HCM, SEM		✓	✓	✓			
(Ferguson et al., 2018)	Canada	HEV, PHEV, BEV	LCM	✓		✓	✓			
(Wang et al., 2017)	China	BEV	MNL, MXL	✓		✓	✓			
(Mersky et al., 2016)	Norway	BEV	RA	✓			✓			
(Hackbarth & Madlener, 2016)	Germany	NGV, HEV, PHEV, BEV, BV, FCEV	MNL, LCM, CV	✓	✓	✓	✓			✓

As can be seen in Table 3.2, despite the importance of analyzing willingness to pay for EVs, no research examined it in Iran. The country is characterized by having abundant fossil fuel reservoirs and potentials in renewable sources simultaneously, having a conventional- powered based transport sector and having the master plan to diversify the energy mix. Therefore, the current study contributed to the surveyed literature in two ways: 1. dividing the influential factors into four levels called macro, micro, product, and psychological and investigating the extent that they can drive consumer's intention towards EVs in four megacities of Iran. 2. conducting the polychoric correlation matrix to identify the optimal factors in the psychological part in explanatory factor analysis, as the Pearson Correlation is not an appropriate method for categorical (5-points Likert scale) variables.

3.4. Sample characteristics

The potential car buyers (ICEV owners) had to meet the following criteria to be qualified as the studied sample:

1. Having a valid driver's license.
2. Owning a car.
3. Be 18 years of age or older.

As mentioned before, the respondents were asked to participate in a Stated Preference Discrete Choice Experiment (SPDCE) for vehicles rather than RP. To increase the accuracy of the answers, the paper-pencil (face-to-face) survey was performed with 1,000 respondents from mid-June to mid-July of 2019. Respondents were recruited from four megacities of Iran (Tehran, Mashhad, Isfahan, and Shiraz), which accounted for 37.1 percent of the total population in 2016. Moreover, to provide detailed information to the participants and explain any ambiguous or complex question to them without making bias in their answers, the well-educated and qualified interviewers were selected from the Statistical Center of Iran. Additionally, followed by the surveyed literature, to assess the impact of electricity sources (oil, Natural gas, coal, and REs) on EV's acceptance, the respondents have been categorized into two different groups (see Fig 3.2.).

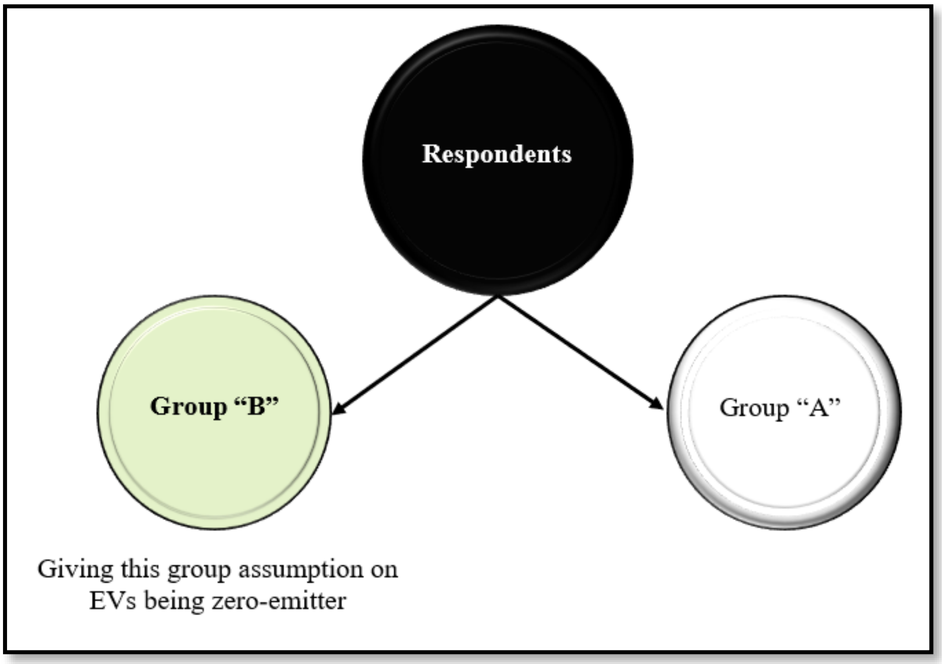


Figure 3.2. Sample of respondents

It was explained to the participants of group A that EVs are not zero- emissions and their environmental impact greatly depends on the sources of required electricity to run it off, vehicle efficiency (Reichmuth Nealer et al., 2015), and the energy wasted in the charging process. For instance, in Norway, electricity is mostly generated from hydropower plants, and therefore EVs are the symbol of the eco-friend vehicle. In contrast, in the biggest EV markets, China, the electricity generation relies on emissions-intensive fossil fuels, especially the coal-fired plant, which reduced the role of EV in environmental concerns (Rachael Nealer, 2015). Accordingly, in 2017 approximately 80.7% of total electricity in Iran has been generated from Natural Gas followed by oil (11.3%), which has ranked Iran as the largest emitter in MENA and the eighth largest emitter in the world (Petroleum, 2019). Therefore, shifting away from fossil fuels into renewable energy, increasing the share of renewables in the electricity generation, penetrating AFVs can decrease the CO_2 emissions caused by the transportation sector. On the other hand, to assess the impact of environmental attitude on the consumer's intention, group B was asked to assume that electricity to charge EV is generated by renewable energy only, meaning no CO_2 and other pollutants emit through the electricity generation process.

3.5. Methodologies

3.5.1. Choice experiment approach

This method is based on the maximization of the random utility function. Indeed, the consumer selects the alternative "*i*" over others, if the utility obtained from the respective alternative is always greater than the utility resulting from choosing other alternatives. Hence, utilizing this method needs a review of potential users. Accordingly, it is a proper technique to determine the RI (value) of each attribute of nonmarket goods or innovative products. Consequently, the willingness to pay for EV in four megacities of Iran could be assessed efficiently by conducting this method (J. H. Kim et al., 2019). In general, in the CE survey, the choice sets, which contains different alternatives and baseline alternatives, were presented to the respondents, and they were asked to choose their most preferred alternative. Each alternative covers different attributes including price/cost attributes. Furthermore, it is a helpful method: 1. To determine the RI of each attribute and 2. To calculate the MWTP for raising or lowering the level of each attribute (Bateman et al., 2002).

3.5.2. Attributes

Identifying the core attributes and assigning their associated levels is the first important thing to provide an appropriate Discrete Choice Experiment (DCE) (Choi et al., 2018). In this regard, by reviewing comprehensive literature and consulting with specialists, five attributes of EVs were chosen. The defined attributes and their corresponding levels were depicted in Table 3.3. It was assumed that all the other attributes, besides the five proposed here, remained at the same level.

Table 3.3. Choice experiment attribute and their levels

Product attribute	**Fuel Type**	 **ICEV**	 **HEV**	 **BEV**
	 Purchase price (USD)	1. 8,000 2. 12,000 3. 16,000	1. 12,000 2. 16,000 3. 20,000	1. 16,000 2. 20,000 3. 25,000
	 Fuel cost per 100 Km (USD)	1. 1 2. 1.5 3. 2 4. 2.5	1. 1 2. 1.5 3. 2 4. 2.5	1. 1 2. 1.5 3. 2 4. 2.5

Service attribute	Availability of charging station (% of gasoline station)	100	100	1. 10 2. 40 3. 70
Pubic policies	 Non-monetary policy	No incentive	No incentive	1. No incentive 2. Access to Bus Rapid Transit (BRT) lanes 3. No restricted driving per plate number 4. Both
A. Choose the most preferred vehicle		○	○	○

Followed by (Noel et al., 2019b), "fuel type" was considered as the first attribute Accordingly, three different car engine technologies were defined, named ICEV, which is gasoline power based, hybrid, and electric.

Based on the studied literature, purchase price and fuel cost were two significant cost-related factors affecting the consumer's willingness to pay for EVs (Helveston et al., 2015a), (Hackbarth & Madlener, 2016), (C. F. Chen et al., 2016), (Wang et al., 2017), (Lin & Wu, 2018), (Huang & Qian, 2018), (Noel et al., 2019b). The purchase price was reported in the US$ unit. Three different levels were defined for each alternative (8000$, 12000$, and 16000$ for ICEV, 12000$, 16000$, and 20000$ for HEV, and 16000$, 20000$, and 25000$ in the case of BEV). Fuel cost was recorded in US$/100 Km with four levels 1, 1.5, 2, and 2.5. These attributes were set based on the actual price and fuel cost of respective vehicle (DENA)sold in Iran's automobile market.

According to the importance of charging station availability in consumer's intention to purchase EV (Yu et al., 2016), (Huang & Qian, 2018), (Choi et al., 2018), (S.-C. Ma et al., 2019), (Nazari, Mohammadian, et al., 2019), (Nazari, Rahimi, et al., 2019), the availability of charging station was considered as the fourth attribute. The associated levels were specified as the percentage of current gasoline station facilities, which was assumed to be 100 percent. In this regard, three options were presented to the respondents, including 10 percent, 40 percent, and 70 percent of the gasoline station.

From the finding of (Wang et al., 2019), and (S.-C. Ma et al., 2019), non-financial incentives policies were the most affordable policies instrument, which were taken as the fifth attribute. Accordingly, four levels 1. No incentive, 2. Access to the BRT lanes, 3. No restricted driving per plate number and 4. Both incentives were determined.

3.5.3. Survey instrument

The questionnaire was designed to gather data and achieve the studied objectives. The finalized questionnaire survey was sectionalized into four parts.

The first part was a descriptive passage on the EVs (HEV and BEV) besides its advantages and disadvantages. The mid-size sedan class called DENA (which is manufactured under a national brand by IKCO) was chosen and participants were asked to state their willingness to pay for its hybrid and electric (battery) versions. The gasoline-powered DENA was illustrated in Fig. 3.3.

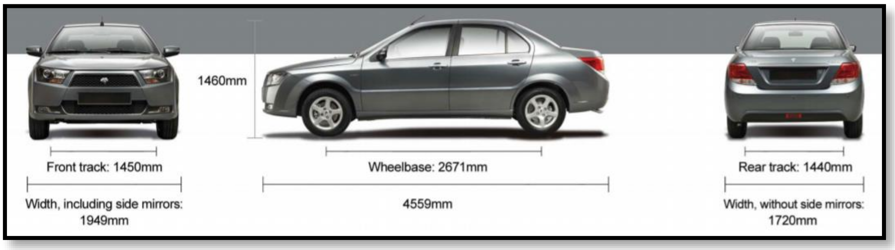


Figure. 3.3. Specifications of the DENA

Source: https://www.ikco.ir

The second part covered the respondent's preferences to EV. This part was comprised of ninth stated choice experiments for each respondent. Furthermore, to increase the validity and accuracy of answers and to check the extent that the respondents were interested in EV, two choice sets with trap options (returning to the first choice set and changing the order of the attributes) were included. However, that choice sets were not counted in the final model. Based on the selected attribute and without any restrictions, it should be 432 (3×3×4×3×4) possible combinations of attributes. Restricting charging availability and non-monetary incentive policies for ICEV and HEV, the total number of possible combinations of attributes has decreased to 168. However, it is difficult to ask respondents to express their preferences to all cases in a questionnaire. Therefore, by implementing the orthogonal experimental design module (orthogonality test), the number of possible attribute combinations was reduced to 25 alternatives. Finally, they have been grouped into three and accordingly 8 choice sets. Briefly, each participant was asked to choose the most preferred options. A sample question was shown in Figure 3.4.

Q1. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	**Vehicle B**	**Vehicle C**
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	8,000	12,000	16,000
Fuel cost per 100 Km (USD)	1	1.5	2
The availability of charging station (% of current gasoline station)	100	100	70
Non-financial policy incentives	No incentive	No incentive	No incentive
○ A. Choose the most preferred vehicle			

Assume that all the other attributes, besides the five proposed here, remain the same

B. Are you willing to purchase the selected car above within 3 years?

Yes □ No □

Figure. 3.4. Sample EV choice set in questionnaire

The third part included not only the socio-economic characteristics of the respondents to make a profile of them and figure out the influencing factors on WTP, but also have some questions about vehicle owned.

Although several aspects influence the adoption rate of EVs, social and psychological factors are amongst the center of decision determinant. Therefore, the fourth part consisted of psychological information, in which the respondents were asked to answer the sentences according to their opinion based on a 5-Point-Likert scale. This scale runs from one to five and indicates strongly disagree, disagree, neutral, agree, and strongly agree, respectively. Moreover, to increase the response rate and to encourage the interviewees to answer questions thoughtfully, some gifts (cash) were awarded randomly to interviewees. The pretest was conducted with the residents and various experts in designing the survey to enhance the design, structure, and language of the study.

Briefly, the conceptual framework of study was presented in Fig 3.5.

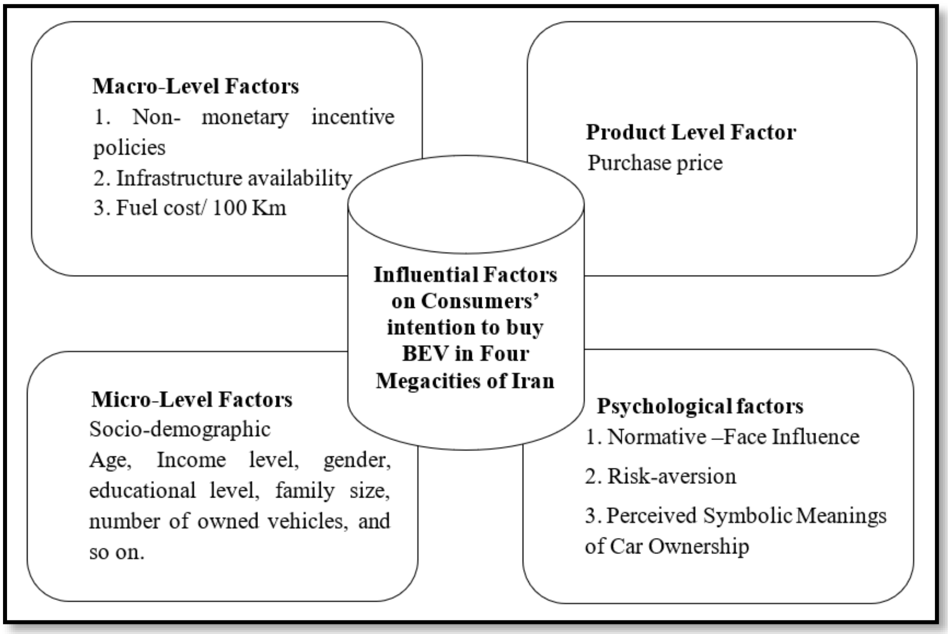


Figure. 3.5. Conceptual framework

3.5.4. Econometric models

3.5.4.1. Utility function and mixed logit model

Because of the discrete nature of the respondent's choice, the discrete choice model is an appropriate model to obtain the research objectives. As discussed before, this model is based on the utility maximization behavior of rational respondents. The levels of defined attributes, namely fuel type, availability of charging stations, fuel efficiency, non-monetary incentive policies (access to the BRT lanes and no restricted driving per plate number), and purchasing price are X_s for $S = 1,2,3,4,5\ and\ p$, respectively. Followed by (McFadden, 1986) and (Train, 2003), the resulting utility from alternative i by decision-maker n could be specified in Eq. (3.1):

$$U_{ni} = W_{ni}(X_{ni}) + \varepsilon_{ni} = \acute{\beta} X_{ni} + \varepsilon_{ni} = \beta_1 X_{1,ni+} \beta_2 X_{2,ni+} \beta_3 X_{3,ni+} \beta_4 X_{4,ni+} \beta_5 X_{5,ni+} \beta_6 X_{p,ni} + \varepsilon_{ni} \quad (3.1)$$

The utility function has been divided into two parts:

1. Stochastic (unobservable) part (ε_{ni}) with independent and identically distributed with Type I extreme values.
2. Deterministic (observable) part (W_{ni}), which contains the vector of the level of attributes (x_{ni}) and their corresponding preference parameter(β_s).

Let assume that $\mathrm{h}(0)$ indicates the probability density function. Followed by (McFadden, 1973) and considering the random utility maximization model, the choice probability that an individual n chooses alternative i over others could be written as Eq. (3.2).

$$\begin{aligned} P_{ni} &= \Pr(U_{ni} > U_{ni}, \forall\ i \neq m) \\ &= \Pr(W_{ni} + \varepsilon_{ni} > W_{nm} + \varepsilon_{nm}, \forall\ i \neq m) \\ &= \Pr(\varepsilon_{nm} - \varepsilon_{ni} < W_{ni} - W_{nm}, \forall\ i \neq m) \quad (3.2) \\ &= \int_{\varepsilon} I\ (\varepsilon_{nm} - \varepsilon_{ni} < W_{ni} - W_{nm}, \forall\ i \neq m)\ h(\varepsilon_n) d\varepsilon_n \end{aligned}$$

Where, the indicator function is shown by $I(0)$. This function takes zero (if the argument is false) and one (otherwise). The MXL model assumes the normal or log-normal distribution for β_n. In MLX model the choice probability that respondent n selects alternative i over others could be shown as Eq. (3.3.).

$$P_{ni} = \int \frac{\exp(\acute{\beta} X_{ni})}{\sum_m \exp(\beta X_{nm})} \, g(\beta) d(\beta) \tag{3.3}$$

Where, g(0) shows the probability density function. the Maximum Simulated Likelihood approach (Train, 2003) was used to deal with the MXL model.

Furthermore, based on the estimated results of Eq.(3.1) and Roy's identity, the MWTP could be calculated as Eq.(3.4). (J. H. Kim et al., 2019). MWTP refers to the economic value that consumers are willing to pay for a unit change in each attribute level.

$$MWTP_{X_s} = -\frac{\partial W / \partial \mathrm{X}_s}{\partial W / \partial \mathrm{X}_p} = -\frac{\beta_s}{\beta_p}, \quad s = 1,2,3,4,5 \tag{3.4}$$

The RI, which explains the significance of each attribute in choosing goods (here, means passenger cars) by consumers could be calculated by using the part-worth of each attribute (Eq. 3.5) (Train, 2003).

$$RI_a = \frac{part - worth_a}{\sum_a part - worth_a} \times 100 \tag{3.5}$$

By multiplying the difference between the maximum and minimum level (interval) of the attribute by the estimated coefficient value of attribute a, the part-worth could be obtained.

3.5.4.2. Latent class model

As explained before, the necessity of relaxing the assumption of IIA in the basic MNL has drawn the researchers and analyst's attention to developing the various discrete choice models (Shen, 2009). Alternatively, based on the LCM, the preference heterogeneity could be considered by using the discrete number of latent classes (Boxall & Adamowicz, 2002), (Morey et al., 2006). This approach has widely been employed in the literature (especially in marketing research) to investigate individual heterogeneity (Greene & Hensher, 2003). Those advantages are being comparatively easy, being statistically testable, and being reasonably plausible. Even though the LCM is a semiparametric variant of the MXL (Geske & Schumann, 2018), it is less flexible than the MXL model, because of assigning fixed value to each (Shen, 2009).

The main assumption of the LCM is the existence of “S” classes. Indeed, the homogenous utility function for the individual within each group and different preferences between classes is assumed (Bujosa et al., 2010), (Hess et al., 2011), (Hackbarth & Madlener, 2016). Two parts are included in the LCM, which could be estimated concurrently: a choice model and a class membership model. Conditional on individual membership to a particular group, the former describes individuals’ choices amongst possible alternatives in several choice situations. While, in the latter, the decision-makers are attributed to the S classes based on the attributes or socio-demographic characteristics.

Assuming the utility-maximizing behavior individual n chooses alternative j out of a set of J alternatives in choice situation t if the highest level of utility could be yielded from the respective alternative in choice situation t. Therefore, the utility function could be shown as Eq. (3.6).

$$U_{njt} = V_{njt} + \varepsilon_{njt} \tag{3.6}$$

The utility function consists of an observable/deterministic part (V_{njt}) and an unobservable part (ε_{njt}). The former could be obtained through multiplying a vector of vehicle alternative's attributes (X_{njt}) by a class-specific vector of the parameter ($\acute{\beta_s}$). The joint probability of the observed sequence of choices of individual n relating to class s could be shown as Eq. (3.7) (Hackbarth & Madlener, 2016).

$$P_{nj|s} = \prod_{t=1}^{T} \frac{\exp(\beta_s \acute{X}_{njt})}{\sum_{j=1}^{J} \exp(\beta_s \acute{X}_{njt})} \tag{3.7}$$

The probability that individual "n" relates to class "s" (H_{ns}), with observable features of the decision-maker (Z_n) and the class-specific parameter vector ($\acute{\theta_s}$), could be shown as Eq. (3.8):

$$H_{ns} = \frac{\exp(\theta_s \acute{Z}_n)}{\sum_{s=1}^{S} \exp(\theta_s \acute{Z}_n)} \tag{3.8}$$

By multiplying Eq. (3.7) and Eq. (3.8), the unconditional likelihood that a randomly selected individual "n" chooses a series of alternatives $j = (j_1, \dots, j_T)$ could be obtained in Eq. (3.9).

$$P_{nj} = \sum_{s=1}^{S} H_{ns} P_{nj|s}$$

$$= \sum_{s=1}^{S} \frac{\exp(\theta_s \acute{Z}_n)}{\sum_{s=1}^{S} \exp(\theta_s \acute{Z}_n)} \prod_{t=1}^{T} \frac{\exp(\beta_s \acute{X}_{njt})}{\sum_{j=1}^{J} \exp(\beta_s \acute{X}_{njt})} \tag{3.9}$$

Since the valid number of consumer groups is unknown, it should be determined by the analyst. The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are amongst those criteria.

3.6. Results and discussion

3.6.1. Descriptive statistics

After removing inconsistent responses, who failed to give the correct answer to the trap option, 576 consistent cases remained to include in the discrete choice model. The sample demographic characteristics were divided into two parts: general demographic information and financial concerns, which were shown through Fig. 3.6 to Fig. 3.7., respectively. From Figure 3.6, similar to findings of (Langbroek et al., 2019), (Zhu et al., 2019), (Zhu et al., 2019), (Helveston et al., 2015a), there were approximately few women (21%) amongst the participants. Regarding the participant's age information, 34% were 21 to 35 years, 45% were aged 35-49, 17% were 49 to 63, while 4% were 63 years or above. 35% of the respondents had a high educational level, meaning that they had completed a college education and had at least a bachelor's degree. Most respondents had families with four or more members. However, three-member families accounted for 32% of the sample. According to the survey, 76.6% of respondents had three or fewer children, and 21.1% of them were childless. 64% of the sample had the plan to buy a new vehicle in the coming 5 years. Amongst the studied participants, 38.5% considered the source of electricity.

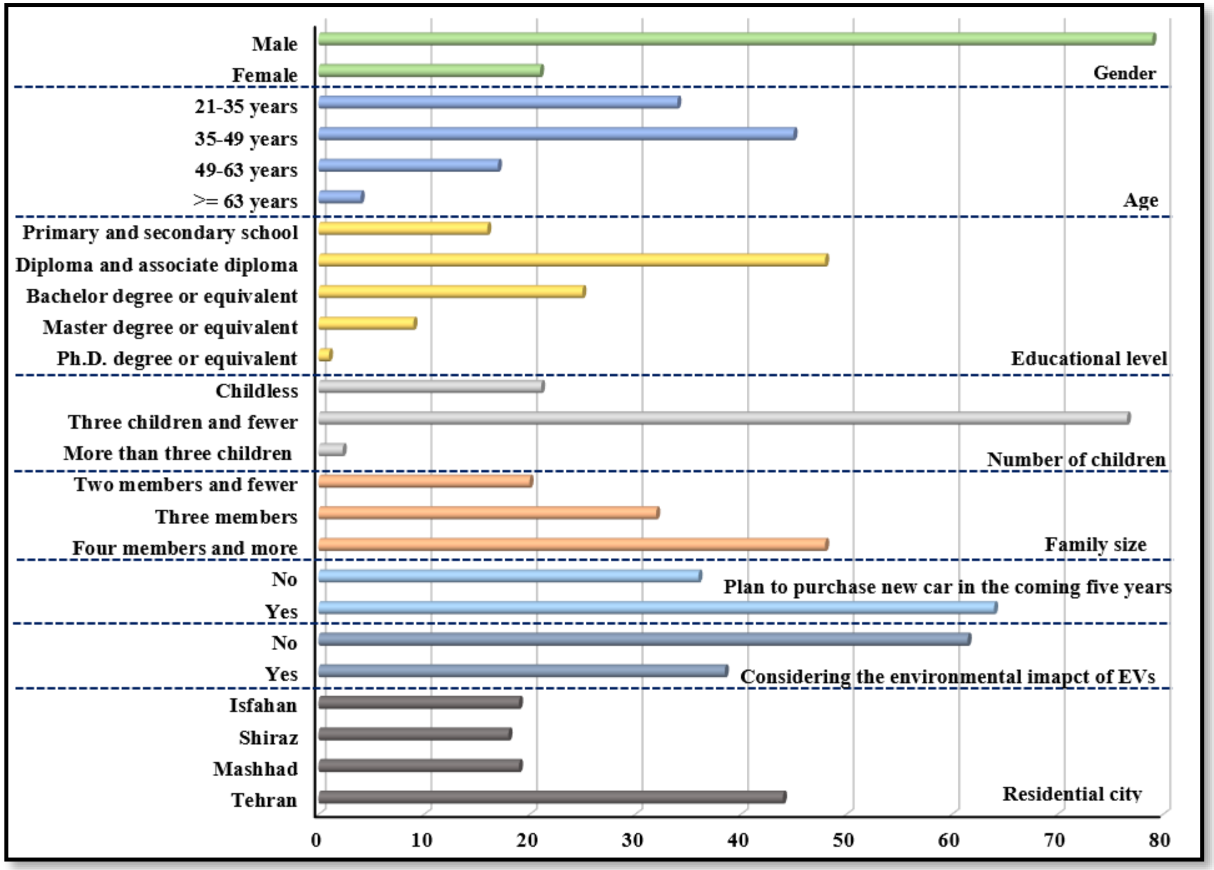


Figure 3.6. Summary of sample general demographic characteristics

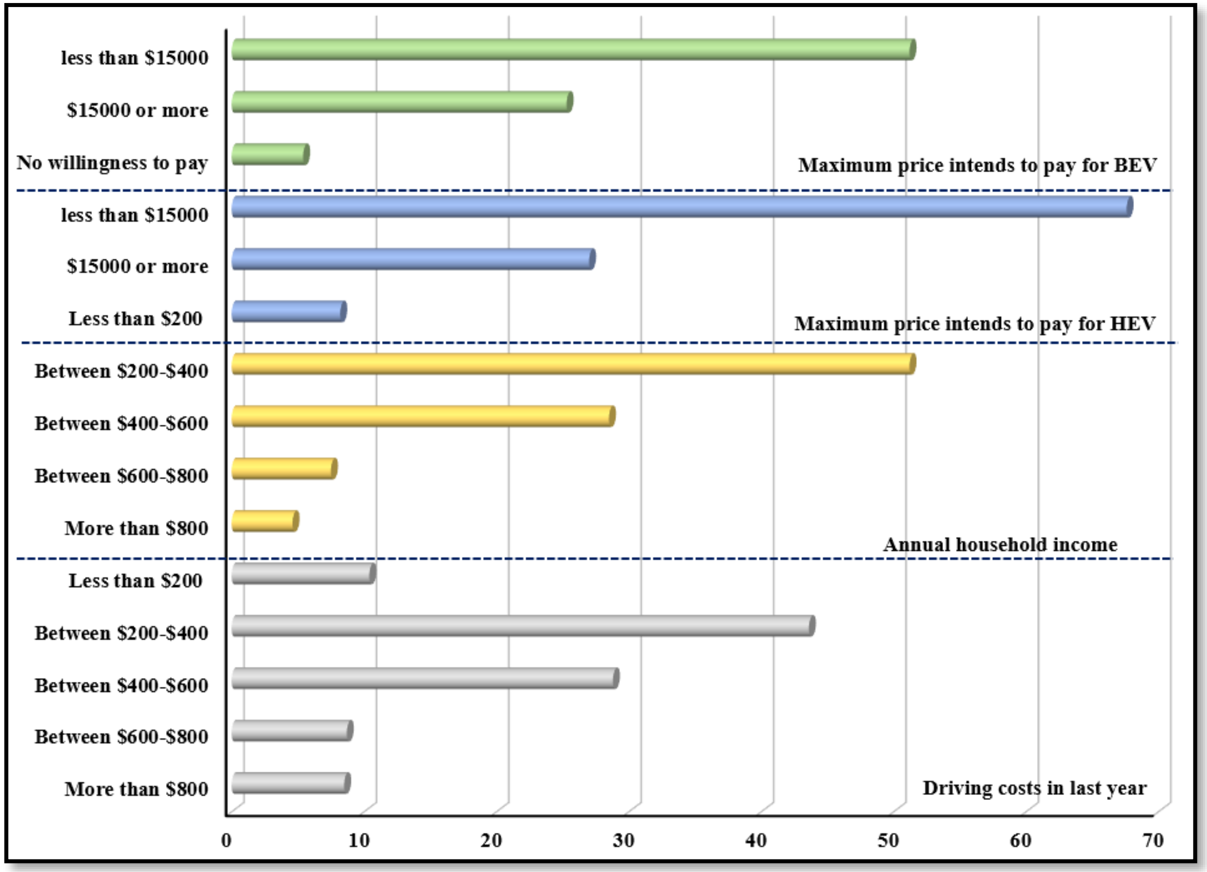


Figure 3.7. Summary of sample financial concern characteristics

It means that they have preferred renewable electricity to electricity generated by conventional fuels. Regarding the distribution pattern of the residential city, the survey revealed that 44%, 19%, %18, and %19 resided in the capital of Iran (Tehran), Mashhad, Shiraz, and Isfahan, respectively.

As shown in Figure 3.7, 5.4% and 23.5% of surveyed participants had no intention to pay for HEV and BEV, respectively. Its implied potential is that consumers HEV to BEV. Of respondents, 27% and 25.3% intended to pay $15000 or more to purchase HEV and BEV, respectively. Amongst the survey participants, 79.7% were classified in the mid-level income group (between $200 to$600), and 8.2% were placed in the low-income class (make less than $200). Paid driving costs (including fuel cost, maintenance, parking, and insurance, so on) last year have shown that 72.4% of studied respondents have spent between $200 to $600, and 10.4% have paid less than $200.

3.6.2. mixed logit model

The results of the MXL, respondents' MWTP for changes in vehicle attributes and RI of each attribute were summarized in Table 3.4.

Table 3.4. Estimation results of the MXL (Number of observations: 13.824)

Attributes	Coefficient	Mean	Variance	MWTP	RI (%)
Fuel type	Baseline (Gasoline)	-	-	-	24.05
	β_1 (Hybrid)	0.736^{***}	6.08^{***}	1131.93	
	β_2(Electric)	-0.206	11.10^{***}	-4082.38	
$\boldsymbol{\beta_3}$ (Purchase Price [a])		-0.002^{***}	0.00^{***}	-	46.40
$\boldsymbol{\beta_4}$ (fuel cost [b])		-0.373^{***}	0.18^{***}	-1103.78	5.46
$\boldsymbol{\beta_5}$ (availability of charging facilities [c])		0.114^{***}	0.00^{***}	43.02	12.88
Non-monetary incentive policies	β_6 (Access to the BRT)	0.352^{**}	0.00	1055.45	11.22

Attributes	Coefficient	Mean	Variance	MWTP	RI (%)
	β_7 (No restricted driving per plate number)	0.791***	0.03	2355.39	

***, and ** indicate 1% and 5% significant level, respectively.
a. Unit: USD
b. Unit: USD per 100 Km
c. Unit: Percentage of current gasoline station

According to Table 3.4, regarding fuel type, the HEVs, which are considered eco-friendly vehicles were the most preferred cars (consumers were willing to pay 1131.9$). This finding could be described by the similarity of HEVs with gasoline vehicles in terms of the operation method (fuel type, not long charging time, and so on). It is noteworthy to mention that BEVs were not preferred to any other vehicle. They intended to pay $4082.38 lesser for BEVs than conventional vehicles (gasoline cars). This result could be explained partially by the lack of knowledge about BEVs in Iran, long charging time, short driving range, etc. Purchase price and fuel costs have negative and significant impacts on willingness to pay, which is intuitively understandable. It implied that potential consumers preferred lower purchase price and fuel costs (pay an extra 1103.78$ to reduce the fuel cost to drive 100 Km). This result is in line with the finding of (J. H. Kim et al., 2019). However, consumer's decisions about electric vehicles is affected positively by the availability of the charging station (paying an extra 43.02 $ per 1% increase in charging facilities). The parameters of non-financial incentives confirmed the positive impact of respective policies on the EVs acceptance rate. Different values for no restricted driving per plate number (0.792), and access to the BRT (0.352), demonstrated the different marginal effects of the respective policies. More precisely, consumers are willing to pay additional 2355.39$ and 1055.45$ for the afore-mentioned policies, respectively. It means that improved infrastructure and providing more incentive policies motivate consumers to switch from conventional vehicles and HEVs to BEVs. The results of the RI of each attribute are depicted in Fig. 3.8. As illustrated in this Figure, the purchase price has the most influential impact on consumer's adoption behaviour (46.405%). The fuel type (24.05%), the availability of charging facilities (12.88%) and non-monetary incentive policies (11.22%), which comprised of no restricted driving per plate number (7.76%) and access to the BRT (3.46%) were set in the second to fifth place in descending order, respectively.

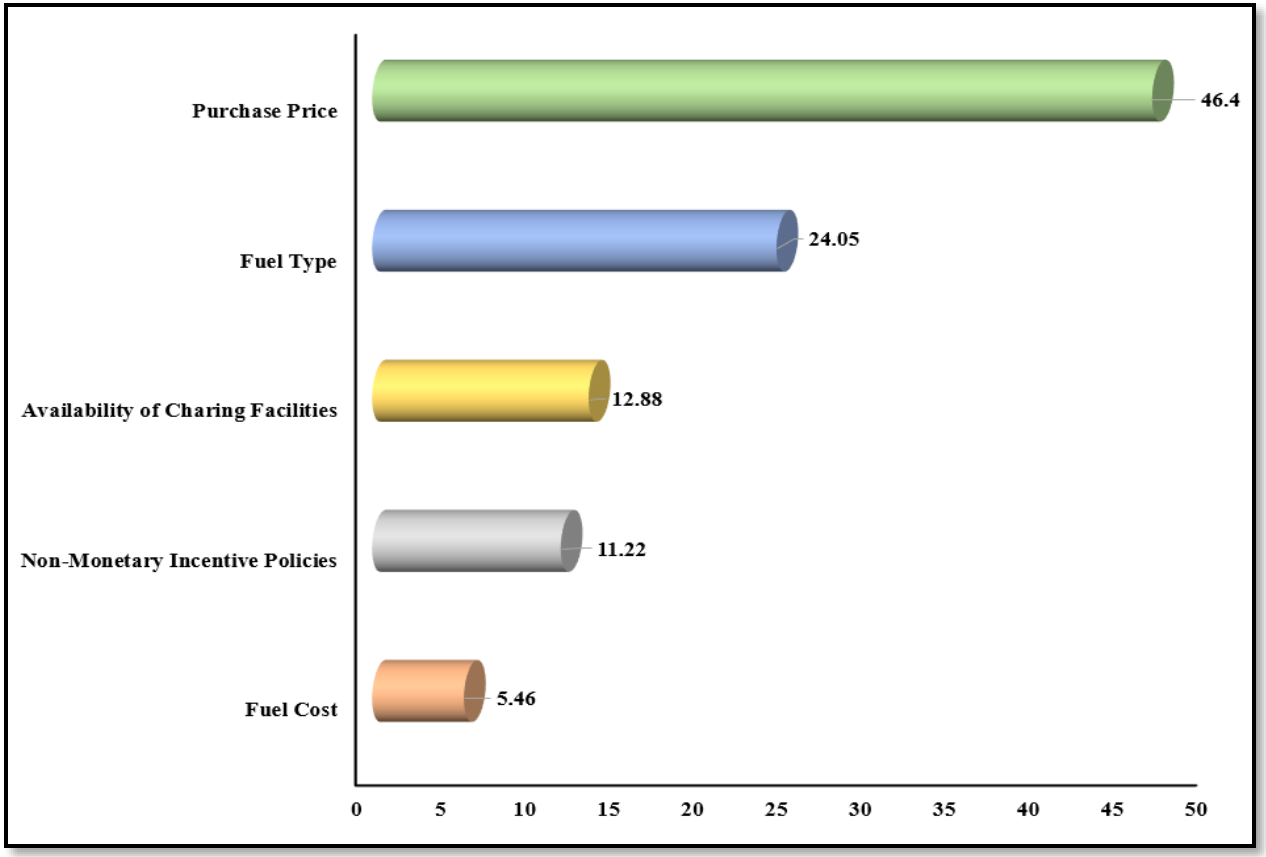


Figure 3.8. The relative importance of each attribute

3.6.3. Market simulation

Using the individual estimated attribute coefficients from the MXL, the impact of infrastructure development and incentive policies on HEVs and BEVs was evaluated by conducting a market simulation. The simulation could be calculated as Eq. (3.10) using the market sample enumeration method (Y. Kim et al., 2007 and Train, 2009).

$$Market\ Share = \frac{1}{N}\sum_{n=1}^{N} P_{ni} \tag{3.10}$$

Where, N is the total number of the interviewee, P_{ni} indicates the probability that alternative i is chosen by decision-maker n from a set of alternatives.

Considering the current situation of attributes in Iran's automotive market, the reference scenario was built. The attributes of HEVs and BEVs were selected based on the most possible options since they have not yet penetrated the market. The proposed scenarios were shown in Table. 3.5.

Table 3.5. Vehicles market share under different policy and infrastructure development

Attribute	ICEV	HEV	BEV	Scenario
Purchase price ($)	8000	12000	25000	Reference
Fuel cost ($/100 Km)	1	1	2.5	
Infrastructure availability (% of gas station)	100	100	10	
Access to BRT lanes	0	0	0	
No restricted driving per plate number	0	0	0	
Market share (%)	**55.6**	**37.7**	**6.7**	
Purchase price ($)	8000	12000	25000	

Attribute	ICEV	HEV	BEV	Scenario
Fuel cost ($/100 Km)	**3**	**3**	2.5	Monetary policy-based (Increased gasoline price three times)
Infrastructure availability (% of gas station)	100	100	10	
Access to BRT lanes	0	0	0	
No restricted driving per plate number	0	0	0	
Market share (%)	**55.1**	**36.9**	**8.1**	
Purchase price ($)	8000	12000	**15000**	Monetary policy-based (introduce subsidy for BEVs)
Fuel cost ($/100 Km)	1	1	2.5	
Infrastructure availability (% of gas station)	100	100	10	
Access to BRT lanes	0	0	0	
No restricted driving per plate number	0	0	0	
Market share (%)	**53.5**	**35.5**	**11.0**	
Purchase price ($)	8	12	25	Non-monetary incentive policy-based
Fuel cost ($/100 Km)	1	1	2.5	
Infrastructure availability (% of gas station)	100	100	10	
Access to BRT lanes	0	0	1	
No restricted driving per plate number	0	0	1	
Market share (%)	**54.6**	**36.1**	**9.3**	
Purchase price ($)	8000	12000	25000	Infrastructure-based
Fuel cost ($/100 Km)	1	1	2.5	
Infrastructure availability (% of gas station)	100	100	**70**	
Access to BRT lanes	0	0	0	
No restricted driving per plate number	0	0	0	
Market share (%)	**55.5**	**37.5**	**7.0**	
Purchase price ($)	8000	12000	**15000**	Combined
Fuel cost ($/100 Km)	**3**	**3**	2.5	

Attribute	ICEV	HEV	BEV	Scenario
Infrastructure availability (% of gas station)	100	100	**70**	
Access to BRT lanes	0	0	**1**	
No restricted driving per plate number	0	0	**1**	
Market share (%)	**47.6**	**29.2**	**23.2**	

- *The monetary policy-based scenarios* cover 1. An increase in gasoline price and 2. Provision of subsidy for BEVs. In the first option, to control environmental hazards caused by the transportation sector and to encourage the consumer to shift away from the conventional fuel-powered vehicle toward BEVs, the gasoline price has increased three times, ceteris paribus. In the second option, to make BEVs affordable and to provide it in competitive prices, the purchase subsidy ($10.000) was introduced, while other attributes were kept unchanged.
- *The non-monetary policy-based scenario* that was built to consider the effectiveness of non-financial incentive policies (access to the BRT lanes and no restricted driving per plate number) on consumer's decisions about EVs.
- The *infrastructure-based scenario* in which to overcome the infrastructure-related problem, the availability of charging stations rose to 70% of the gasoline station.
- The *combined scenario* included four afore-mentioned types of changes in the attributes

The vehicle's market share was depicted in Fig 3.9 to consider the effectiveness of each scenario.

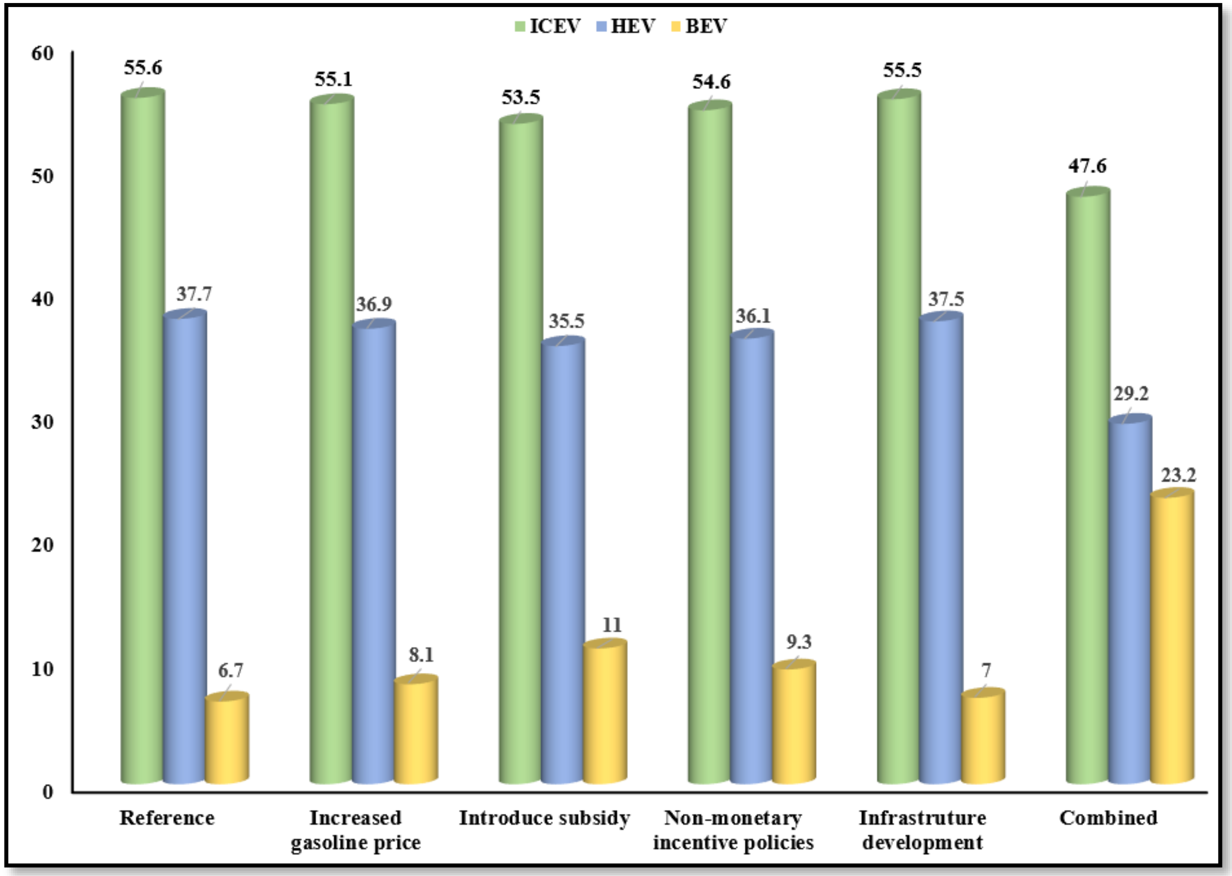


Figure 3.9. Vehicle's market shares in different scenarios

As illustrated in Fig 3.9, the share of CEV, HEV, and BEV in the reference scenario was 55.6, 37.7, and 6.7 percent, respectively. Therefore, in this scenario, the ICEV had a dominant share of the market. In all investigated scenarios, the share of BEV has been extended. The change in BEV's market share in each scenario is depicted in Figure 3.10. According to this Figure, change in BEV's market share could be listed as follows in descending order: combined scenario (16.6%), introducing subsidy (4.3%), providing non-monetary incentive policies (2.6%), increased gasoline price (1.4%), and increasing the charging station to 70% of the current gas station (0.3%). The results revealed the impact of price on the consumer's willingness to pay for BEV. More precisely, a 10.000 dollar decrease in the BEV price increases its market share by 4.3%. As expected, the increase in market share in the combined scenario was much bigger than the summation of all studied scenarios (16.6%> 4.3%+2.6%+1.4%+0.3=8.6). This finding could be explained partly by the heterogeneity among potential consumers (different preferences and different importance assigned to each attribute and the existence of interrelationship among individual scenarios) due to the nonlinearity nature of choice probability function. To gain a better understanding of the issue, see the Figure 3.11.

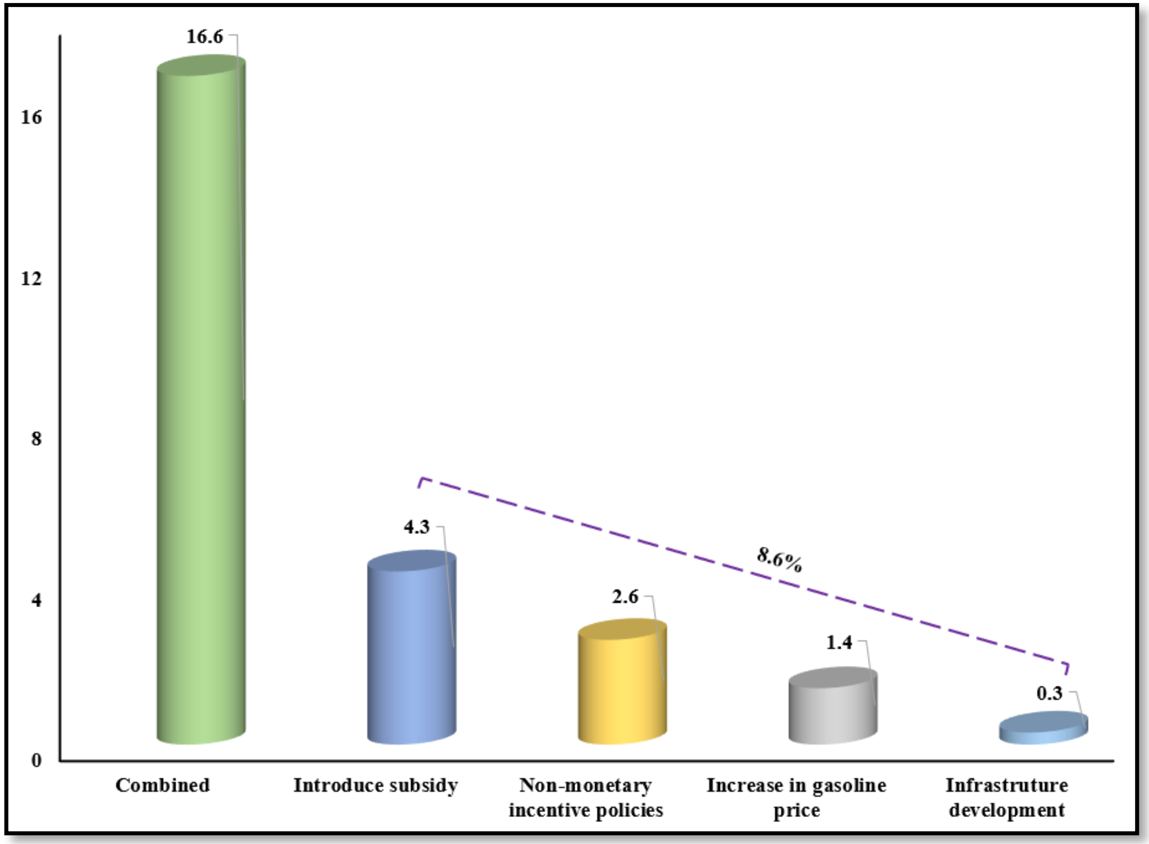


Figure 3.10. BEV's market share in each scenario

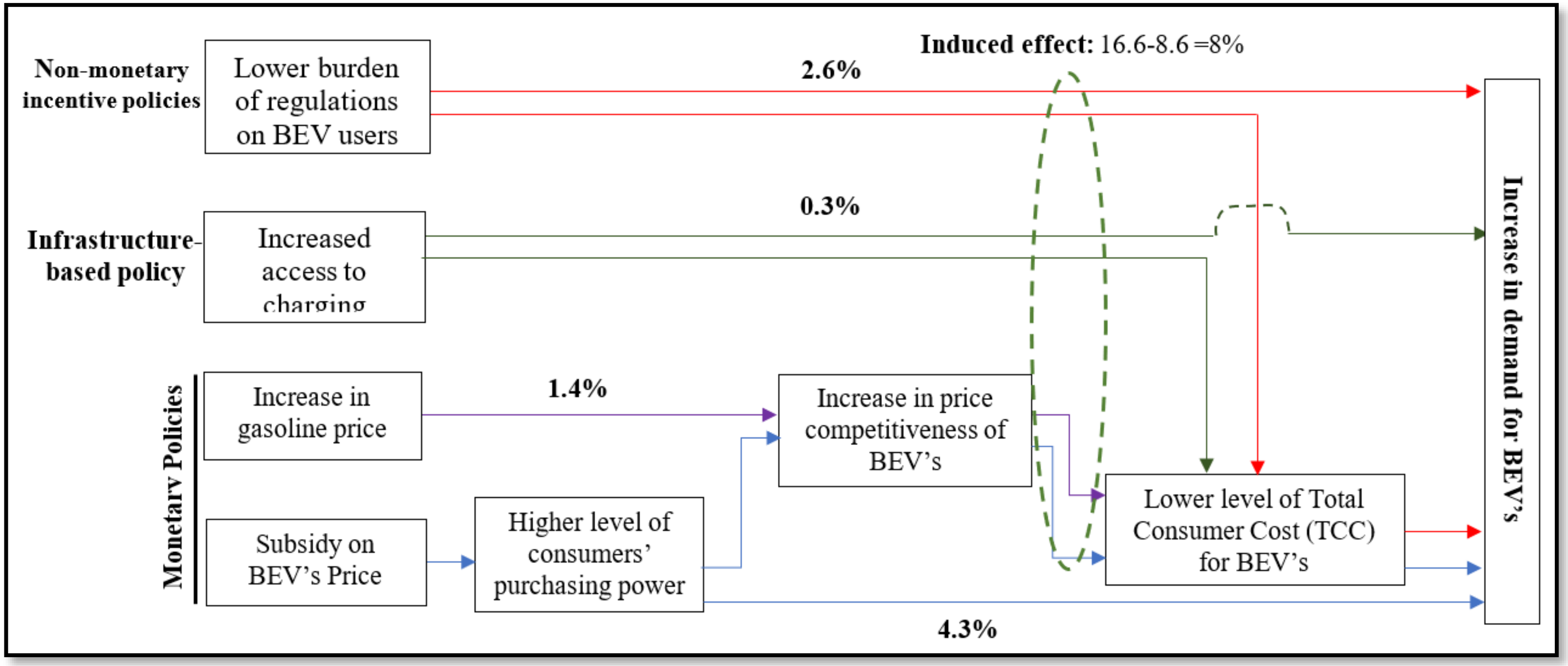


Figure 3.11. Synergy effects of combined scenarios

From Figure 3.11, each scenario provokes the demand for BEVs via the direct and induced effect.

1. Non-monetary incentive policies directly by lowering the burden of regulation on BEV users provokes its demand by 2.6%. Moreover, this policy indirectly increases the demand for BEVs by reducing the level of Total Consumer Cost (TCC) for BEVs (induced effect). It's noteworthy to mention that in an emergency condition, people have to purchase permission to drive on impermissible days.

2. Infrastructure-based policies increase the demand for BEVs by 0.3% (direct effect). Furthermore, improving the required infrastructure induces its demand indirectly by reducing the TCC (induced effect).

3. An increase in gasoline price increased the demand for BEVs through increasing the price competitiveness of BEVs (1.4%) and induced effect (lowering the level of TCC for BEVs).

4. Introducing subsidy for BEVs provoke the demand for BEVs through increasing consumers' purchasing power (direct impact 4.3%). The induced effects of this policy can be explained by increasing price competitiveness of BEVs and lowering the level of TCC for BEVs.

In closing, the induced effect of all scenarios is 16.6%-8.6%=8%.

3.6.3. Latent class membership

To include the psychological character of the participants in the LCM model, in the first step, the respondent's psychological factors were asked using the 5-points Likert scale (1= "strongly disagree'' and 5= "strongly agree''). More precisely, the respondent's perceptions of *normative influence* (Bearden et al., 1989), *face influence, risk aversion* (Bao et al., 2003) and *perceived symbols of car ownership* (XUE et al., 2013) are investigated. To this end, the Exploratory Factor Analysis is performed to check the extent that the measurement of four-items (*normative influence*, *face influence*, *risk aversion*, and *perceived symbols of car ownership*) could be reduced to latent factors (Huang & Qian, 2018). However, it's noteworthy to mention that the Pearson correlation could not be considered as a proper method to assess the strength of the relationship between ordinal (categorical) variables like Likert scale (Holgado–Tello et al., 2010). First of all, the Pearson correlation is based on the interval measurement scale assumption (Gilley & Uhlig, 1993). Second, as the Pearson correlation decreases with sample homogeneity, the strength of the relationship between observed variables could be underestimated. Consequently, the factor weightings earned from the factorization of the correlation matrix could be reduced (Holgado–Tello et al., 2010). To overcome this deficiency, (Jöreskog & Sörbom, 1996) proposed the "Polychoric Correlation as the most consistent and powerful estimation method, which is free from population correlation and the sample size. The optimal number of factors is determined by employing the proposed Parallel Analysis by (Horn, 1965). Indeed, using the Monte Carlo Simulation Technique, the simulative database and corresponding eigenvalues are generated. Consequently, the number of factors is defined where the eigenvalue in actual data is smaller than simulative ones (Çokluk & Koçak, 2016).

The Bartlett test (2156.9) and the Kaiser-Meyer-Olkin (KMO) test (0.78225) confirmed the sphericity and adequacy of sampling, respectively. Moreover, the significant correlation among the investigated variables was supported. It indicated the goodness of performing factor analysis on respondent's psychological information (Jaiswal & Kant, 2018). By using the permutation of the raw data to obtain the random correlation matrix (Buja & Eyuboglu, 1992), the optimal number of factors were identified and summarized in Table 3.6.

Table 3.6. Polychoric correlation matrix results

Factor	**Real data eigenvalues**	**Mean of random eigenvalues**	**95 percentiles of random eigenvalues**	**Cumulative variance**
1	3.83707*	1.26955	1.33924	0.31976
2	1.76792*	1.19793	1.24156	0.46708
3	**1.40360***	**1.14522**	**1.18313**	**0.58405**
4	0.96160	1.09724	1.13009	

* Advised number of dimensions: 3

From Table 3.6, three factors, which explained about 59 percent of the total variance were extracted as the optimal number. By using the Weighted Varimax Rotation, the results of factor loading were reported in Table 3.7.

Table 3.7. Psychological measures and factor loadings.

Constructs	Items	Rotated factor loading	Component
Normative Influence (Bearden et al., 1989)	When purchasing products, I usually purchase the brands that I think others will approve it	0.575	C1
	If people can see me using a product, I often purchase the brand they expect me to purchase	0.710	
	If I want to be like someone, I often try to get the same brands that they buy	0.610	
Face perspective (Bao et al., 2003)	Sometimes, I buy a product because my friends do so	0.518	
	Name-brand purchase is a good way to recognize some people from others	0.616	
	Name products and brand purchases can bring me a sense of prestige	0.608	
Risk aversion (Bao et al., 2003)	I am cautious in trying innovative/new products	0.721	C3
	I would rather stick with a brand I usually buy than try something I am not very sure of	0.816	
Perceived symbolic meanings of car ownership (XUE et al., 2013)	Car-ownership is a symbol of wealth status	0.599	C2
	Car-ownership is a symbol of convenience status	0.866	
	Car-ownership is a symbol of comfort	0.891	
	Car-ownership is a symbol of freedom	0.770	

Based on Table 3.7, normative influence and face perspective were loaded together as a component and were called normative-face influence. The perceived symbolic meaning of car ownership and risk aversion was loaded independently. By multiplying the loaded factors in 5 points Likert scale, the weighted average was calculated and added into the LCM to evaluate the impact of psychological factors on potential consumer's intention to EVs.

In the next step, the socio-demographic variables (age, gender, monthly income), environmental concerns, and psychological factors normative-face influence, perceived symbolic meaning of car ownership, and risk-aversion) were considered to explain the class membership. The results of LCM with three classes were summarized in Table 3.8.

Table 3.8. Latent Class Model with three classes

Attribute	Class 1		Class 2		Class 3	
	Coef.	P>z	Coef.	P>z	Coef.	P>z
HEV	3.2012	0.000	1.093	0.000	-0.4364	0.000
BEV	1.6274	0.001	2.803	0.000	-1.210	0.001
Purchase price	-0.00022	0.000	-0.00006	0.000	-0.00028	0.000
Fuel cost per 100 Km	-0.4163	0.007	-0.3500	0.002	-0.3843	0.000
Availability of charging station	0.0032	0.624	0.0127	0.001	0.0066	0.248
Access to Bus Rapid Transit (BRT) lanes	0.0327	0.936	0.4190	0.020	0.6780	0.032
No restricted driving per plate number	0.1851	0.682	0.6110	0.000	0.4858	0.055
Class share	21.1%		18.4%		60.5%	
	Class 1		Class 2		Class 3	

Attribute	Class 1		Class 2		Class 3	
	Coef.	P>z	Coef.	P>z	Coef.	P>z
Class membership variable	Coef.	P>z	Coef.	P>z	Coef.	P>z
Age	-0.5283	0.039	0.1165	0.633	Reference Class	
Gender	0.1641	0.555	0.2181	0.444		
Monthly income	0.0009	0.046	0.0010	0.04		
Environmental concerns	0.4159	0.095	0.3820	0.139		
Normative-face influence	0.4015	0.175	-0.4890	0.098		
Risk aversion	-0.1156	0.495	-0.3920	0.024		
Perceived symbolic meanings of car ownership	-0.1912	0.924	0.2226	0.294		
Constant	-0.3168	0.687	-0.5085	0.541		

As illustrated in Table 3.8, having 21.1 % of the total sample, the member of the first group more prefers HEVs, BEVs, and ICEVs in descending order. Therefore, this group could be called the HEV-oriented group. The main findings of class membership for this class could be summarized as follows:

- A person's propensity to purchase HEV compared to conventional fuel-powered vehicles increases with youth. This results is consistent with the findings of (Hidrue et al., 2011), (Achtnicht, 2012), (Hackbarth & Madlener, 2013), (Shin et al., 2015), (Hackbarth & Madlener, 2016);
- Consistent with the previous studies such as (Hackbarth & Madlener, 2013), (Lai et al., 2015); (Sang & Bekhet, 2015), (Orlov & Kallbekken, 2019), the environmental attitude have significant impacts on the adoption rate of EVs. In other words,

environmentally informed consumers are more inclined to buy HEVs.

- Higher-income earners appear to prefer the HEVs to the conventional fossil fuel-powered vehicles in the reference/ base class.
- Their intention to purchase HEVS Not affected by psychological characters (normative-face influence, risk aversion, and perceived symbolic meanings of car ownership).

Owning 18.4 percent of the total sample, the members of the second class, less prefer ICEV, HEV, and BEV in increasing order. Hence, they could be called BEV-oriented group. They were less sensitive to the purchase price and fuel cost. However, the non-financial incentive policies (no restricted driving per plate number (0.611), access to BRT lanes (0.419)), and availability of the charging station (0.0127) are significant factors in encouraging consumers to buy BEVs in declining order. The principal conclusions from class membership could be listed as follows:

- High-income individuals seem to like buying BEVs compared to the first class.
- Consistent with the surveyed literature such as (Oliver & Rosen, 2010), (Petschnig et al., 2014), (Qian & Yin, 2017), (Huang & Qian, 2018), risk-aversion negatively influences consumer's intention to BEVs. It indicated the dubiousness of consumers toward new technology. Indeed, the risks related to these vehicles such as providing service facilities appropriately and the immaturity of the technology could explain this result.

- In contrast to the previous studies like (Lane & Potter, 2007), (X. He & Zhan, 2018), (Huang & Qian, 2018), (Al Mamun et al., 2018) the normative-face perspective have not had a positive impact on consumer's willingness to pay for BEVs. The coefficient of this parameter (-0.4890) was statistically significant at a 10% significant level. Since BEVs have not yet penetrated the Iranian market, this result could be explained partly through the Diffusion of Innovation (DOI) theory. Based on this theory, in a social system, individuals do not adopt an innovation simultaneously. Consequently, based on the relative timing of adoption, the adopter could be categorized into five groups: 1. innovators; 2. early adopters; 3. early majority; 4. late majority, and 5. laggards (Rogers, 2010). Indeed, the innovators are ready to face the risk of profitless and unsuccessful innovations since they intend to experience new ideas. The unusual risk-taking behavior of this group has made them unacceptable by other members of the social system. Briefly, in the first step of developing the new idea, the innovators do not pay attention to the normative and face perspective factors.

3.7. Limitations and future researches

Although, the result of this research provides significant insights into the willingness to EVs and provides vital information to the government, policymakers, and automakers to formulate strategies and policies to stimulate the penetration of EVs into the market, there are some limitations, which can be listed as follows:

i. Owning a vehicle has been the requirement to include the participants in the survey and to measure their willingness to pay for vehicle fuel type. Future researches are suggested to estimate the decisions of fuel type and vehicle ownership by considering households without a vehicle to extend this series of studies. Therefore, one can estimate the impact of travel patterns on vehicle fuel type and vehicle ownership simultaneously.

ii. The obtained outcomes of this study have been estimated employing the SP hypothetical choice experiment method approach based on the current market status. Indeed, consumer preferences have been measured regarding different attributes. However, over time, the consumer's preferences to the EVs can be rearranged through increasing the consumer's awareness about these types of vehicles and introducing the latest technological innovation. Therefore, future studies can be conducted by adding additional attributes such as monetary and non-monetary incentive policies, vehicles' model/brand, recharging time, battery replacement cost, and so on. Moreover, the findings of this study can be compared to the results from RP in the future.

3.8. Conclusions and recommendations

Global warming and concerns about the depletion of fossil fuels have assigned more attention to EVs as an alternative for conventional fuel-powered vehicles to overcome environmental issues caused by road traffic. However, different vehicle electrification technologies have various environmental (air emissions) and national security consequences.

From a national security perspective, BEVs substitute gasoline completely, while HEVs reduce gasoline consumption. The environmental impacts of BEVs could be identified by the electricity generation mix and battery manufacturing. However, efficacious penetration of EVs to the market requires considering both sides of the market, namely supply and demand.

To control the environmental side effects of transportation sectors in Iran and to commit the obligation to the Paris agreements, the government and policy-makers have initiated the master plan to substitute the gasoline-powered vehicles with the AFVS. However, people's tendency and willingness to pay for these types of vehicles should be considered as well.

This chapter estimated the consumer preferences for EVs among the residents of four megacities of Iran. Questionnaires were distributed among 1,000 respondents, 576 cases remained to include in the discrete choice model. It can be stated that the variety in the modeling of the willingness to pay by above-mentioned car drivers in our sample is supported by the applied analytical model. It is noteworthy to mention that due to the IIA restriction of the MNL model, the MXL model was used as an econometrically advanced analytic model. Accordingly, three categories of attributes called product type (fuel type, purchase price, and fuel cost per 100 Km), service availability (charging station availability as a percentage of gasoline station), and public policies (two non-monetary incentive policies) were tested. Furthermore, LCM was employed to analyze the heterogeneous preferences among respondents.

Unlike previous studies, the impact of psychological characteristics of the respondents on their intention towards the EVs has been evaluated in this study. To this end, 12 psychological factors have been included in the LCM in the form of the 5-point Likert scale. The explanatory factor analysis was employed to reduce the latent factors of the subjective attributes of participants. However, the polychoric correlation matrix was applied, instead of the Pearson correlation matrix, which is mostly used in the previous researches to determine the optimal number of factors, as the former is not a suitable method for categorical variables, such as the 5-point Likert scale. Moreover, to evaluate the degree of consumer preferences, the MWTP and RI were calculated. Employing the market simulation, the impact of infrastructure development and incentive policies on consumer's intention toward HEVs and BEVs was evaluated.

The results of MXL model, MWTP and RI, showed that price is an essential factor, which negatively affects the probability of adopting EV. The higher is the price, the lower the intention to purchase becomes. Indeed, high purchase price remained the most significant consumer's concerns about EVs, followed by the fuel type (engine technology), the availability of charging stations, and non-monetary incentive policies. Hence, individuals are more likely to purchase EVs by improving significant attributes. The scenario analysis showed that conventional-powered vehicles remained as the dominant vehicles in terms of market share. Market share in combined scenario is much bigger than the summation of all studied scenarios, which could be explained by heterogeneity among potential consumers (different preferences and different importance assigned to each attribute) and the synergy effects of all policies. From the finding of LCM, the interviewees were classified into three groups as follows:

1. ICEV-oriented group as a reference group (60.5%).
2. HEV-oriented group (21.1%). The younger people were recognized as potential buyers of this group. This finding could be used to target specific populations in marketing. It means that to

increase the share of HEV, the government and automakers should focus on this target group to improve their attitudes toward HEV.

3. BEV-oriented group (18.4%), which preferred BEV and HEV to ICEV. No restricted driving per plate number (0.611), access to BRT lanes (0.419), and availability of the charging station (0.0127) were significant factors in encouraging the members of this group to buy BEVs in declining order. Risk-aversion reduced members' willingness to pay for BEVs, which arose from the dubiousness of consumers toward new technology.

No need to mention that the high- income group, which is characterized by good economic foundation was amongst most significant potential buyers of HEV and BEV.

The recommendations are proposed based on the different types of government interventions (market-based and non-market-based).

i. Direct market-based interventions

- Price regulation in EVs market through launching supportive package such as providing soft loans at 1. preferential rate, 2. long term payback period, and 3. interest holidays. And passing discounts on raw material prices used in the production of EVs.
- Price re-regulation through gradual fossil fuel price liberalization to catch up international level and reallocate financial resources from subsidy reform to invest in public transport sector.
- Increasing purchase power and convert potential demand into actual ones through providing lease financing at preferential rates for applicants to purchase EVs and Electric Motorcycles.

- Provoking demand for HEV and BEV through 1. providing more economic incentive for the young people and low-income group and improving vehicles' performance to provoke demand for these innovative-based vehicles for all income-groups. 2. developing the required technology of public and private charging stations through endogenous development and relying on the capability of universities, research centers, and knowledge-based companies. 3. providing subsidy for EV parking construction and supply facilities installation. 4. providing discount or cash for replacing ICE-based vehicles with EVs.

ii. Indirect market-based interventions

- Increasing the public awareness and knowledge about EVs performance through providing education-related advertising and marketing, teaser campaigns and holding specialized exhibitions, workshops, seminars, and conferences.
- Providing R&D investment incentives for EVs manufacturers through: 1. returning a portion of the Research and Development costs to the units. 2. considering the research expenses as tax eligible costs (R&D). Besides, facilitating technology transfer from developed nations in the form of licensing, joint venture, Joint R&D, Strategic alliance, and so on.

iii. Non-market-based interventions

- Since the auto market in Iran is a duopoly (not a perfectly competitive market), the market-based policies are not an appropriate policy. In this case, the government must shift to the non-market-based (command and control) policies such as imposing competition regulation in both the fossil fuel-based vehicles and EVs to prevent uncontrolled price increase through setting the annual quota regulation for car manufacturers in both gasoline-powered based vehicles and EVs,

- Establishing rules for cross-sectoral coordination amongst involved institutions in the production, distribution, service, and supervision of EV.
- Restructuring the economic structure of interest rate to provide better environment and to support investment in the EV's sector.

Chapter 4

Barriers to Renewable Energy Technologies Penetration: Perspective in Iran

4.1. Introduction

The rapid fossil fuels demand growth rate has pushed the government and policymakers to take numerous initiatives to identify alternative sources to manage the efficient use of conventional fuels, to increase its supply security, and to protect the environment (Mahama et al., 2020 and Ansari et al., 2013). In this regard, renewable energy technologies have emerged as the appropriate option for power generation around the world. These technologies have numerous economic, social, and environmental benefits, and are a proper way to achieve the goal of sustainable development. However, there are various impediments to the development path of REs in all countries around the world, particularly in developing countries such as Iran (Wilkins, 2010 and Nalan et al., 2009). Notwithstanding the increasing trend in utilizing Res during recent years, investigated literature demonstrated numerous barriers in their developing path. High initial capital cost; lack of awareness on renewable sources, and inadequate knowledge about technology's benefits were recognized as the most significant obstacles (Rezaee et al., 2019).

being located in South-West Asia and specifically between two main world energy focus, called the Persian Gulf and the Caspian Sea, gives Iran a strategic position in energy supply and security. Indeed, surrounded by 15 land and sea neighbours, Iran is signified as a beneficial trade and transit route in both North-South and East-West corridors. Due to this specific geographical location and climate, it has a high potential in renewable energies. Despite having huge potentials, it has not reached a significant progress yet. The share of renewable energy in the energy mix (1%) and electricity generation is still low in 2018 (BP, 2020). Consequently, the government and policymakers have paid little attention to explore alternative energy sources (renewable energy) (Gholamhasan Najafi et al., 2015). Therefore, finding suitable solutions to overcome these barriers requires identifying, analyzing, and ranking the main obstacles to the development path of renewable energy according to their importance, which is the main purpose of this chapter. This chapter intends to answer two following questions:

1. What are the barriers to the development of REs in Iran?
2. What is the most suitable REs in Iran among solar PV, wind power, and biomass?

To answer the abovementioned questions, the rest of this chapter is structured as follows: Section-2 devotes to literature review. Section-3 identifies the main and sub-barriers to the development of Res technologies in Iran based on the literature review and expert's point of view. Section-4 illustrates the used methodology, while Section-6 exhibits results and discussion. Section-5. Limitation and future research are elaborated in Section-6. Lastly, the chapter by drawing conclusions and exposing the recommendations in Section-8.

4.2. Literature review

Notwithstanding the increasing trend in utilizing REs during recent years, investigated literature demonstrated numerous barriers in their developing path. High initial capital cost; lack of awareness on renewable sources, and inadequate knowledge about technology's benefits were recognized as the most significant obstacles (Rezaee et al., 2019).

In this respect, Mirza et al., (2009) have classified the main barriers to renewable technology adoption in Pakistan into six groups, including market-related barriers; policy and regulatory; institutional; fiscal and financial, technological, and information and social.

Nalan et al., (2009) have evaluated the market conditions of REs and identified the key obstacles. Based on their results the cost of technologies, economic, financing, and technical and scientific were realized as the most challenging problems.

Achievement of the goal of increasing the share of REs in the energy mix of Korea to 11% by 2030 required identifying and ranking the effective criteria and factors. To this end, using fuzzy AHP, Heo et al., (2010) have reviewed seventeen factors and classified them into five groups, called market-related, economic, environmental, technological, and policy.

Mondal et al., (2010) showed the potential of Bangladesh in renewable technologies like min-hydropower, solar, wind, and biomass. Moreover, this country gradually has shifted away from fossil fuels to renewable sources to boost economic development in rural areas. However, they pointed out that achieving this goal requires overcoming three main obstacles. They have classified these barriers into 1. Social (low public awareness and knowledge on REs), 2. Economic (high initial capital cost), and 3. Policy and regulatory (lack of well-defined policies for encouraging private sector).

Using a questionnaire and survey of practice, X. Zhang et al., (2012) has classified the main limitations of the diffusion of the solar photovoltaic energy system in the case of Hong Kong into four categories. Those barriers have been listed as economic and financial (high initial and repair cost, long payback period), technical (inadequate installation space, and service infrastructure), regulatory and legal, and political & government issues (lack of stakeholder participation in energy choices).

Employing the Analytical Hierarchy Process (AHP) technique, (Luthra et al., 2015) has identified twenty-eight barriers that reduce the adoption rate of renewable energy in India. They have ranked those barriers into seven dimensions called ecological and geographical, political and government issues, technical, economic, and financial, awareness and information, cultural and behavioural, and market -related restrictions in descending order, respectively.

Reviewing surveyed literature on technological innovation system and system function, Eleftheriadis & Anagnostopoulou, (2015) have identified twenty-two key barriers to the development of photovoltaic solar power and wind in the electricity sector of Greek. Based on the result of their study, the lack of sufficient financial resources, low local communities' acceptance to construct wind farms, delay in issuing building permits, the low grid capacity, and the existence of unstable institutions were realized as the most critical challenging problems.

Nasirov et al., (2016) have investigated the opportunities and barriers to reducing dependence on energy sources imports, and to expand utilizing renewable energy in Chile. Their results showed that despite improving the regulatory framework and incentive policies to the development of renewable energy, their mass penetration needs to overcome several barriers. Those limitations could be summarized as regulatory and institutional, technological and infrastructure, financial and economic, market-related, cultural, and social, and awareness and information, in descending order.

Karatayev et al., (2016) have described the high potential of renewable energy and have shown that increase in utilization of these sources could lead to social, economic, and environmental benefits in the context of Kazakhstan. However, the share of renewable electricity in the electricity generation mix is low (less than one percent), therefore to identify the main barriers to scale up renewable energy, they have deployed the AHP approach and ranked them into five groups including 1. Economic and financial, 2. Technical, 3. Institutional, 4. Market failure, and 5. Society and culture.

Sindhu et al., (2016) have identified thirty-six important obstacles to extend the utilization of solar power in the Indian context and categorized them into seven groups. Based on the results of the AHP model, the political and regulatory, high cost of capital, institutional, finance, marketing, technical, and social, cultural, and behavioural were realized as the most important challenging problems in the path of diffusion of solar power in descending order, respectively.

To identify and rank the barriers of adopting renewable energy in Nepal , Ghimire & Kim, (2018) have recognized twenty-two barriers and classified them into six groups in terms of their importance: policy and political, economic, geographic, administrative, social, and technical.

Shah et al., (2019) have employed a systematic framework to array the barriers that hinder REs adoption rates in Pakistan. The authors have taken three steps. 1. Identifying the barriers by studying the literature survey; 2. Finalizing twenty-first barriers using the Modified Delphi method and classifying them into five categories called social, political regulatory, market competitiveness, technical, and institutional. 3. Calculating weights and ranking barriers and sub-barriers by employing the Fuzzy Analytical Hierarchical Process (FAHP). Based on their results, the main barriers have been summarized as political and regulatory, market competitiveness, technical, social, and institutional, in decreasing order, respectively.

Mahama et al., (2020) have studied and ranked the barriers that hinder renewable energy adoption rate in Ghana. The authors have identified nineteen obstacles and categorized them into six groups, called market-related, economic, and financial, technical, legal & regulatory framework, human skills, and socio-cultural restrictions. Based on their results, economic and financial, technical, and human skills were identified as the most critical challenging obstacles.

To overcome the barriers to the development of Mini-grids in Myanmar as a decentralized approach to achieve the goal of 100% electrification by 2030, Numata et al., (2020) have employed the AHP model and K-means clustering method. They have studied five categories, named Technical, regulatory, economic, social/cultural, and financial. Their finding confirmed the lack of a single dominant solution. Using Multi-Objective Optimization based on Ratio Analysis (MULTIMOORA) combined with the Evaluation based on Distance from Average Solution (EDAS) method, Asante et al., (2020) have reviewed twenty-three barriers of developing REs in Ghana and classified them into six categories. According to their results, the political and regulatory obstacles were identified as the most challenging barrier that impedes REs development. The most related studies on barriers to reduce the renewable energy adoption rate are summarized in Table 4.1.

Table 4.1. Summary of studies on barriers to the development of REs

Study	Location		Main Criteria										
		ENV	EF	TECH	M	TECHN	SCB	PR	INS	AI	EG	ADM	HS
(Mirza et al., 2009)	Pakistan		✓		✓	✓	✓	✓	✓				
(Nalan et al., 2009)[1]	Turkey		✓	✓									
(Heo et al., 2010)	South Korea	✓	✓		✓	✓		✓					
(Mondal et al., 2010)	Bangladesh		✓				✓	✓					
(X. Zhang et al., 2012)[2]	Hong Kong		✓	✓				✓					
(Luthra et al., 2015)	India		✓	✓	✓		✓	✓		✓	✓		
(Nasirov et al., 2016)[3]	Chile		✓		✓	✓	✓		✓	✓			
(Karatayev et al., 2016)	Kazakhstan		✓	✓	✓		✓		✓				
(Sindhu et al., 2016)[4]	India		✓	✓	✓		✓	✓	✓				
(Ghimire & Kim, 2018)	Nepal		✓	✓			✓	✓			✓	✓	
(Shah et al., 2019)	Pakistan			✓	✓		✓	✓	✓				
(Mahama et al., 2020)	Ghana		✓	✓	✓		✓	✓					✓
(Numata et al., 2020)[5]	Myanmar		✓	✓			✓	✓					
(Asante et al., 2020)	Ghana		✓	✓			✓	✓	✓		✓		

[1]. The authors have classified the cost of technology, economic, and financing barriers in the separate groups. However, to keep compatibility among studies, those barriers were considered as a group.
[2]. It should be noted that the authors have classified 1. Regulatory &legal, and 2. Political & government issues into two separate classes.
[3]. The authors have considered institutional and regulatory factors as the same criteria.
[4]. It noteworthy to notice that the authors have considered the high cost of capital and finance as two different criteria.
[5]. The authors have categorized economic and financial factors as the different criteria

From the surveyed literature, the importance of REs depends on the socio-economic, technological, and technical potential, geographic (location), and political circumstances. Consequently, failure to study these impediments may lead to the formulating inappropriate related policies. Therefore, understanding and identifying the barriers is the necessity of designing suitable strategies. While several studies have investigated the impediments to the adoption of energy-efficient technologies in different developing countries, no research has been conducted for Iran.

This chapter contributed to the literature in three ways. 1. The result of this research may provide the basic framework for the government, the policymakers, the managers, the private sector, and the executors involved in designing and formulating the inclusive REs projects in the developing countries like Iran, 2. A comprehensive literature review on the barriers to the development of REs has been presented in this study (2009-2020), which can assist the interested researchers in this field, 3. The most crucial contribution of this paper is identifying and ranking the hindrance to the development of REs in Iran to overcome the barriers and find a way to increase its share.

4.3. Barriers identification in Iran

The main barriers to the development of REs resources in Iran were identified in three steps (Figure 4.1).

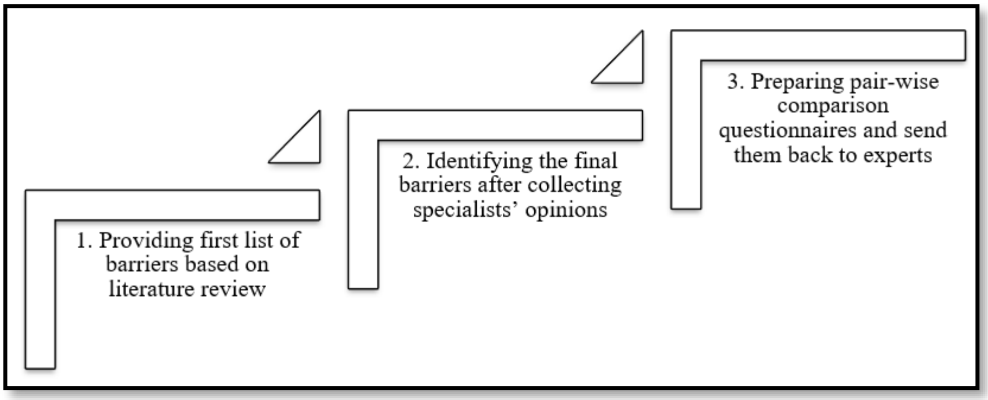


Figure 4.1. Steps to identification barriers in Iran

Firstly, the initial list was provided from the literature review by using searching keywords such as REs (as a whole or by fuel type) development, barriers, issues, challenges in Iran on several search engines such as Google, Google Scholar, Science Direct, Springer, Scopus, and so on. Then, the final list was extracted by collecting the specialists and experts' opinion and modifying the draft based on the specific country's circumstances (by adding some unconsidered barriers to the list and removing some from the list). These experts were selected from the Ministry of Petroleum, the Ministry of Energy, and Petroleum University of Technology. Finally, to rank the main obstacles to the adoption of REs resources in Iran, the final list of barriers was presented to experts again. Lastly, 13 hindrances were identified and classified into five main categories. The ultimate barriers list and their relevant references in the literature were summarized in Table 4.2.

Table 4.2. Final list of barriers to the development of REs in Iran

Criteria	**Sub-criteria**	**Key references**
Economic & financial	The absence of private and state section's investors (EF1)	(Pegels, 2010), (Ansari et al., 2013), (Eleftheriadis & Anagnostopoulou, 2015), (Karatayev et al., 2016), (Rezaee et al., 2019)
	Lack of access to credit and long payback period (EF2)	(Atabi, 2004), (Mondal et al., 2010), (Fadai et al., 2011), (X. Zhang et al., 2012), (Ansari et al., 2013), (Eleftheriadis & Anagnostopoulou, 2015), (Karatayev et al., 2016), (Ghimire & Kim, 2018), (Rezaee et al., 2019), (Shah et al., 2019), (Mahama et al., 2020)
	High initial investment, high costs of renewable technologies (providing subsidy for fossil fuel) (EF3)	(Mirza et al., 2009), (Nalan et al., 2009), (Pegels, 2010), (Mondal et al., 2010), (Ghorashi & Rahimi, 2011), (X. Zhang et al., 2012), (Luthra et al., 2015), (Verbruggen et al., 2010), (Karatayev et al., 2016), (Nasirov et al., 2016), (Sindhu et al., 2016), (Ghimire & Kim, 2018), (Shah et al., 2019), (Rezaee et al., 2019), (Mahama et al., 2020), (Asante et al., 2020), (Numata et al., 2020)
Social, cultural, & behavioral	Lack of social acceptance (SCB1)	(Kardony, 2013), (Karatayev et al., 2016), (Ghimire & Kim, 2018), (Rezaee et al., 2019),

Criteria	Sub-criteria	Key references
		(Shah et al., 2019), (Asante et al., 2020), (Numata et al., 2020)
	Low public awareness (SCB2)	(Mirza et al., 2009), (Mondal et al., 2010), (Rezaei et al., 2013), (Luthra et al., 2015), (Sindhu et al., 2016), (Karatayev et al., 2016), (Nasirov et al., 2016), (Ghimire & Kim, 2018), (Rezaee et al., 2019), (Shah et al., 2019), (Asante et al., 2020), (Mahama et al., 2020)
Political & regulatory	International sanctions (PR1)	(Rezaee et al., 2019)
	The absence of proper international cooperation with the International REs Agency and World Bank (PR2)	(Rezaee et al., 2019)
	The absence of sustainable energy and environmental policies (PR3)	(Mirza et al., 2009), (Nalan et al., 2009), (Fadai et al., 2011), (Ansari et al., 2013), (Eleftheriadis & Anagnostopoulou, 2015), (Luthra et al., 2015), (Ghimire & Kim, 2018), (Shah et al., 2019), (Rezaee et al., 2019), (Asante et al., 2020)
Technical	Lack of infrastructure facilities (TECH1)	(Atabi, 2004), (Rezaee et al., 2019), (Mahama et al., 2020), (Asante et al., 2020)
	Lack of skilled personnel (TECH2)	(Mirza et al., 2009), (Fadai et al., 2011), (Karatayev et al., 2016), (Afsharzade et al., 2016), (Shah et al., 2019), (Asante et al., 2020)

Criteria	Sub-criteria	Key references
	The absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc. (TECH3)	(Rezaee et al., 2019)
Institutional	The absence of active banks and insurance companies in renewable energies (INST1)	(Rezaee et al., 2019)
	The absence of an appropriate structure for encouraging and supporting REs use and development (INST2)	(Nalan et al., 2009), (Ansari et al., 2013), (Rezaee et al., 2019)

Each barrier and sub-barriers are explained in detail in the next parts.

4.3.1. Economic and financial aspect and sub-criteria

Economic and financial barriers are amongst the most crucial obstacles to hinder the successful development of REs technologies in developing countries such as Iran. The most significant restrictions could be listed as the low intention of private and public investors to invest in renewable energies, lack of access to credit and long payback period, high initial investment, high cost of renewable technology, more subsidy for conventional fuels compared to REs (Raza et al., 2015), (Moorthy et al., 2019). The subsidies that the government of Iran allocated to fossil fuel sources is much higher than what is provided to the REs (Oryani et al., 2020). This supportive program has led to the high cost of renewable technologies compared to their counterpart. The lower efficiency of REs has increased its *net payback period*. On the other hand, the development of these energies needs *high initial costs*. Therefore, it has decreased the *private and state investor's attitudes toward investing in RES*.

4.3.2. Social, cultural, and behavioral aspect and sub-criteria

The shift away from conventional (fossil fuels) resources toward REs have faced public opposition and resistance. This case could be described by the lack of public awareness about the advantages of renewable sources and the lack of social acceptance (Blechinger & Richter, 2014), (Moorthy et al., 2019). The most significant problems about *public consciousness* could be summarized as low awareness of modern technologies such as renewable energy technology (RET), and doubts about the economic feasibility of renewable sources constructing projects (Nasirov et al., 2015). People have various attitudes about renewable sources, probably somebody resistant to *accept these technologies*. More precisely, preferences toward conventional fuels, lower local cooperation to the development of renewable sources, and lack of information and knowledge about these types of energies could act as the resistance to change the energy consumption patterns from fossil fuels to renewable ones (Painuly, 2001).

4.3.3. Political and regulatory aspect and sub-criteria

The inadequacy of policies and regulations to support the expansion of REs could decrease the adoption rate of these technologies. Indeed, increasing the investor's interest in the REs market requires formulating the transparent policies and legal procedures because of the nature of REs structures. Considering the specific conditions in Iran, the most influential factors could be summarized as the *international sanctions, the absence of appropriate international cooperation with the International Renewable energy Agency (IREA) and the World Bank*, and *the absence of sustainable energy and environmental policies*. As mentioned earlier, The nature of the processes of the energy transition is capital intensive and need large amounts of primary investment and technology, particularly in developing countries such as Iran (Donovan, 2015). This issue has led to the high dependence of these countries on the financial support and technology transfer from advanced nations to achieve the goal of GHG emissions reduction. Following the lifts of the economic sanctions in 2016, Iran has increased the oil exports, gained access to the Foreign Exchange Reserve Funds (FERF), returned back to the international financial system, and drawn foreign investor's interest in the main sectors. However, re-imposing the sanctions reduced foreign investments and limited technology transfers, and lowered the interaction with the international organization, which has put Iran's energy policies away from renewable sources (Hazrati & Malakoutikhah, 2019). Having an efficient regulatory framework in the energy sectors is crucial to achieving the goals of sustainable development, and could solve the incoherence between conventional and modern energies (Moorthy et al., 2019). Therefore, the lack of appropriate policies to bring REs technology to the global market, the absence of governmental agencies, inadequate confidence in RET, and the lack of sustainable energy and environmental policies are amongst the significant obstacles to the expansion of REs projects (H. Zhang et al., 2014).

4.3.4. Technical aspect and sub-criteria

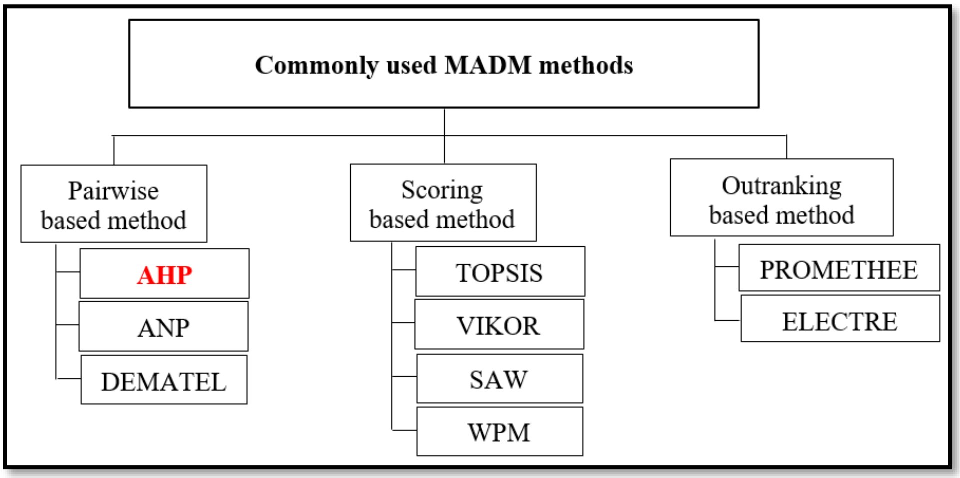
The weak and non-existent required infrastructure is one of the most crucial impediments in the expansion of modern energy technology (RET) in developing countries like Iran (Shah et al., 2019). Indeed, the successful management and operation of RET need trained and skilled personnel such as technicians, technical experts, engineering and policy experts (Kumar & Katoch, 2015). However, it is noteworthy to be noticed that the quality of the education systems and the supportive provided program determined the supply of well-educated labors. Furthermore, due to the high dependence on the fossil fuels in Iran, the absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc. has emerged as one of the hindrances to the development of RET.

4.3.5. Institutional aspect and sub-criteria

Institutional barriers such as the absence of active banks and insurance companies in REs and the absence of an appropriate structure for encouraging and support of REs use and development are amongst the most crucial impediments to the expansion of RET in Iran.

4.4. Methodology: analytic hierarchy process

Multi-Attribute Decision-Making Method (MADM) is widely used to determine the way to process the information on attributes to choose the most appropriate possible choice amongst the set of alternatives. Generally, there are compensatory and no compensatory ways to this process. In the former, the trade-offs amongst attributes are allowed, while it is not permitted in the latter. Furthermore, because of the different form and depth of the attributes from the decision-makers' judgments point of view, the additional arrangement was created. A decider might not show his preferences anymore or might present his choice via attributes or alternatives. Moreover, the various decision information on attributes might be classified in the ascending scale of complexity as standard level, cardinal, ordinal, and marginal rate of replacement. Therefore, the MADM methods are categorized to meet these various circumstantial judgments (Tzeng & Huang, 2011). The most commonly MADM methods in the literature can be divided into three groups called pairwise comparison, scoring, and outranking method (Fig. 4.2).



Source: (Ilbahar et al., 2019)

Figure 4.2. Classification of commonly used MADM techniques

These methods are frequently employed in the REs field, For instance, to identify the most appropriate energy source, to assess energy policies and energy source performance, to find the most suitable location to establish an energy plant, to choose the most desirable energy technology, and to identify the main barriers to the development of the energy (Ilbahar et al., 2019). Amongst other methods, the AHP is one of the most commonly implemented MADM technique to investigate sustainable energy and renewable technology-related problems (Kahraman, 2008). Therefore, the AHP is employed to identify and rank the main hindrance to the development of the most applicable REs technologies in Iran, called solar PV, a wind power, and biomass.

The AHP could be used as a robust method to solve the complex and unorganized problems, which may have correlations and interactions among various objectives (D. S. Chang & Sun, 2007). This method assists the decision-maker in identifying the crucial dimension of a problem into a hierarchical arrangement comparable with a family tree (Zaim et al., 2012). Indeed, it is an experts' judgments-based model through making pairwise comparisons. Lastly, the overall preferences are generated to rank the intended alternatives (Thomas L. Saaty, 1980). The AHP could be conducted in five stages as follows:

1. Structuring the hierarchy based on the defined goal of the research, identified criteria, sub-criteria, and alternatives. Indeed, considering the 13 identified sub-barriers within five main criteria, the decision-making problem has been decomposed, and the hierarchal structure was constructed (Thomas L. Saaty, 1990a) (Figure 4.3.).

As illustrated in Figure 4.3, the identified barriers and sub-barriers were reported in four levels as follows:

i. The main goal of research.
ii. The priority of main dimensions
iii. The priority of related sub-barriers within dimension.
iv. The overall ranking of barriers to the development of alternatives.

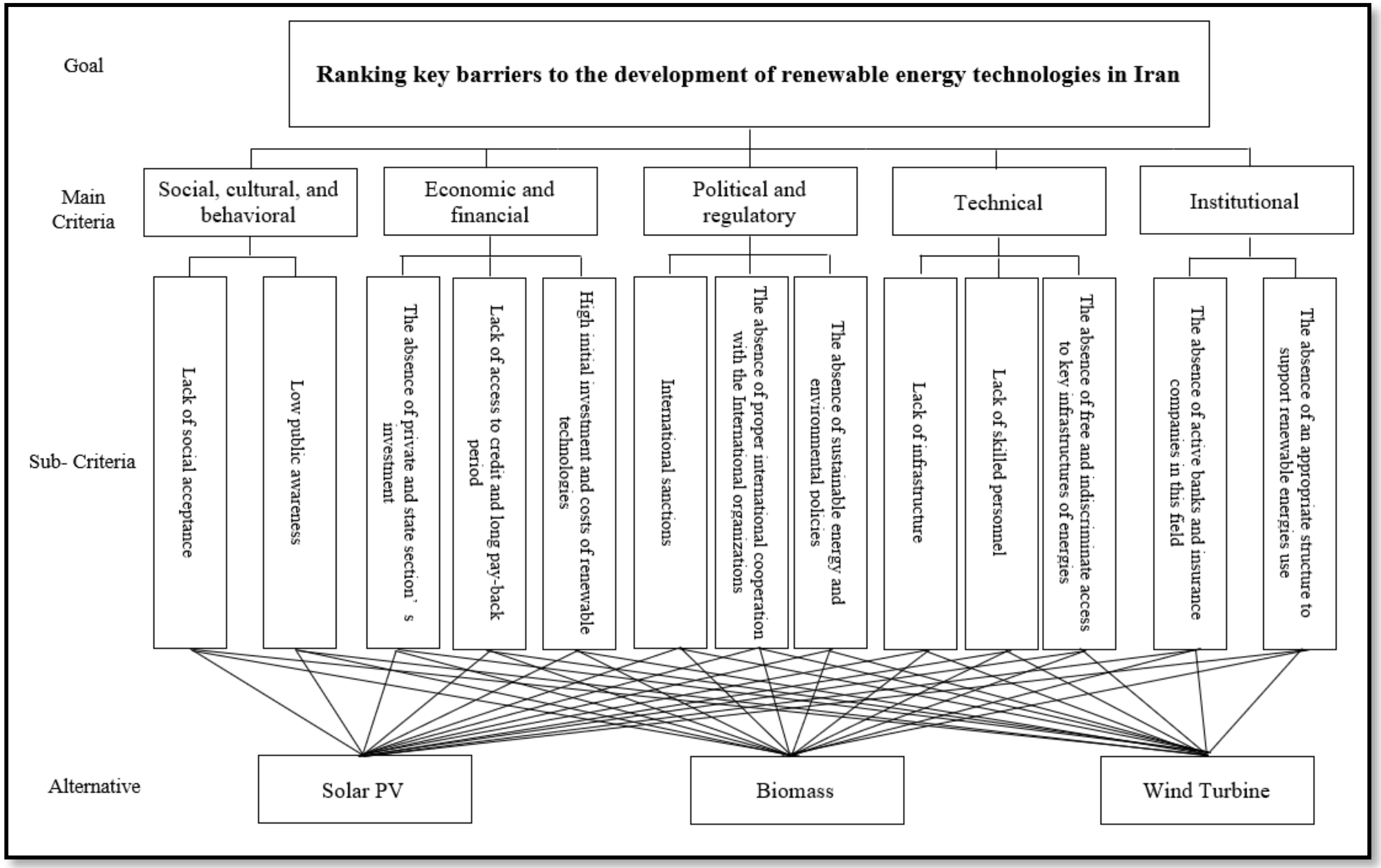


Figure 4.3. Hierarchical structure of the barriers to the development of REs in Iran

2. Formulating the pair-wise comparison questionnaire. In this stage, the specialists were asked to make pair-wise comparisons between criteria and sub-criteria based on a nine-point scale (R. W. Saaty, 1987), which was shown in Table 4.3.

Table 4.3. Selecting numerical scales for pair-wise comparisons

Explanation	**Numeric scale**
If option A and B have the same importance	1
If option A is moderately more important than option B	3
If option A is strongly more important than option B	5
If option A is very strongly more important than option B	7
If option A is extremely more important than option	9
Choose even numbers for intermediate evaluation	2, 4, 6, 8

Source: (Thomas L. Saaty, 1986), (R. W. Saaty, 1987), (Thomas L. Saaty, 1990b), (Thomas L. Saaty, 1990a), (T. L. Saaty, 2002)

3. Constructing the pair-wise comparison matrix regarding the goal and sub-barriers in each category (main criteria). Subsequently, the combined pair-wise comparison matrix has been created by performing the geometric mean of all experts' judgment (Thomas L. Saaty, 1986).

4. Estimating the weight of main and sub-barriers by employing Eq. (4.1).

$$Aw = \lambda_{max} \times w \tag{4.1}$$

Where: A stands for priority (comparison) matrix of size $n \times n$, in which n shows the number of main criteria, w indicates the priority weight (Eigenvector) of size $n \times 1$, λ_{max} represents the maximum eigenvalue (Thomas L. Saaty, 1990a), (Thomas L. Saaty, 1990b). Several techniques are available to determine the priority vector.

Amongst them, normalizing the geometric mean of the rows is the simplest way (R. W. Saaty, 1987).

5. Checking the consistency of estimation using the Consistency Ratio (C.R.) from Random Index (R.Ix.). The standard values of R. Ix. is listed in Table 4.4.

Table 4.4. Values of R. Ix.

n	1	2	3	4	5	6	7	8	9	10
$R.I.$	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.40	1.49

Source: (Thomas L. Saaty, 1990a)

The consistency index could be calculated as Eq. (4.2) (Thomas L. Saaty, 2006)

$$C.I. = \frac{\lambda_{max} - n}{n - 1} \tag{4.2}$$

The consistency ratio could be calculating using Eq. (4.3).

$$C.R. = \frac{C.I.}{R.Ix.} \tag{4.3}$$

4.5. Results and discussion

4.5.1. Category hierarchy results

The overall aggregated results of five categorized barriers dimensions hierarchy were illustrated in Figure 4.4. According to this Figure, the overall aggregated results from all specialists in Figure 4.4 demonstrated the most notable deterrent effect of economic and financial barriers (51.5%) on the development of REs in the context of Iran. Following that, the social, cultural, and behavioural barriers (20.1%), the technical barriers (12.8%), the political and regulatory barriers (10.1%), and the Institutional barriers (5.6%) took the second to the fifth places, respectively.

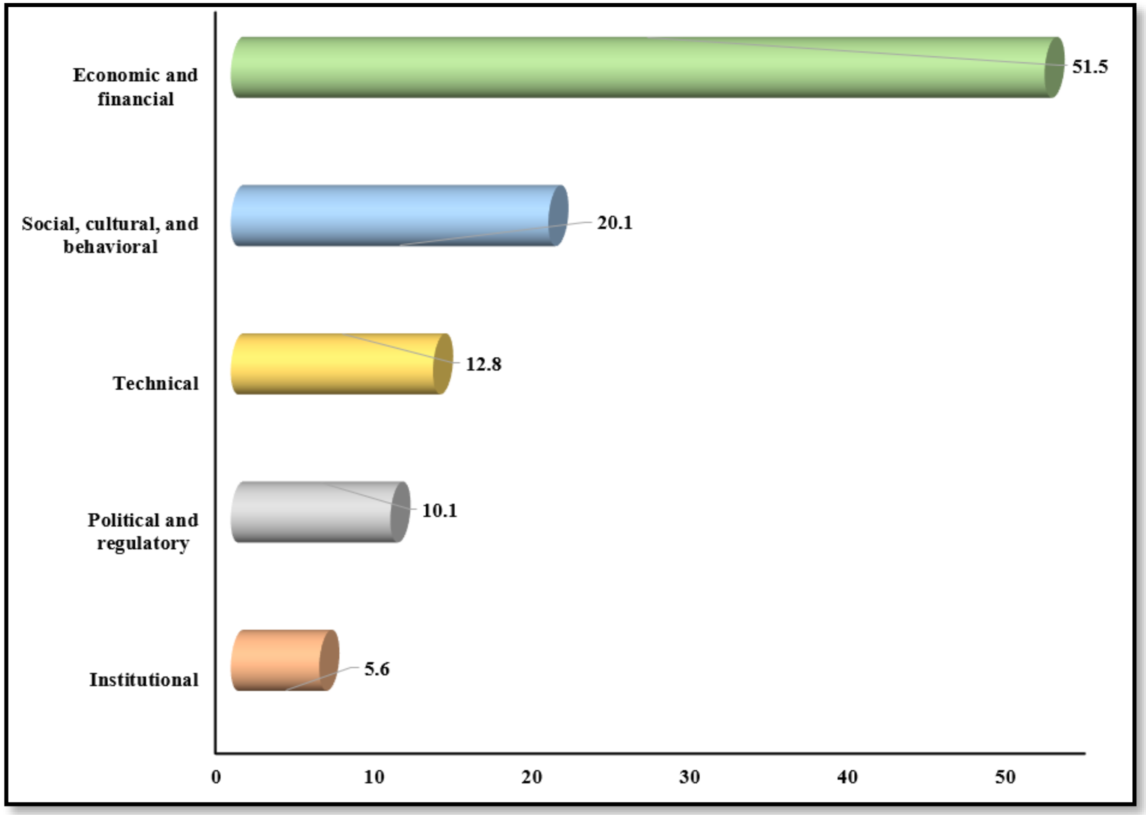
4.5.2. Ranking of barriers within categories

Synthesis results showed that the *absence of private and state section's investment* (45.1%) was the most significant barrier to the development of REs in the economic and financial category. *The high initial investment*, *and the high costs of REs* (29.8%), and *lack of access to credit and long payback period* (25.1%) were ranked as second and third obstacles, respectively.

For the social, cultural, and behavioral dimension, *the lack of social acceptance* (55.8%) was the biggest hindrance to the development of renewable energy, followed by *low public awareness* (44.2%).

The *international sanction* (52.3%) was the most significant barrier to hinder the path of REs development within the political and regulatory category. *The absence of sustainable energy and environmental policies* (24.9%) and t*he absence of proper international cooperation with the International REs Agency (IREA) and World Bank* (22.9%) took the second and third place, respectively.

In the technical barriers, *the lack of skilled personnel* (49.9%) was detected as the most significant barrier to the development of renewable energy, followed by *the absence of free and indiscriminate access to crucial energies infrastructures such as national electricity network, etc.* (32.8%), and the *lack of infrastructure facilities* (17.4%).



Consistency Ratio (CR): 0.00392

Figure 4.4. Synthesize of Dimensions and Prioritization

Lastly, *the absence of active banks and insurance companies in REs* (67.3%), and *the absence of an appropriate structure for encouraging and support of REs use and development* (32.7%) were identified as the first and the second obstacles to the expansion of REs in the institutional dimension. The ranking of synthesized results in each category was reported in the appendix part C.2, in detail.

4.5.3. Global ranking

The overall weights of each barrier in hindering the path of REs development could be calculated by multiplying the priority weight of that barrier to the importance of the relevant main dimension. The overall ranking of barriers was illustrated in Figure 4.5. As displayed in the Figure, *the absence of private and state section's investment* (21.1%) was ranked as the main barrier to the development of REs in Iran. L*ow public awareness* (14%), *high initial investment, and high costs of renewable technologies (providing subsidy for fossil fuel)* (13.8%), *lack of access to credit and long payback period* (13.3%), and *the lack of skilled personnel* (7.3%), *the lack of social acceptance* (6.6%), and *international sanction* (5.7%) have stayed in the second to fifth places, respectively. The remaining 18.2% has been related to *the absence of free and indiscriminate access to key infrastructures of energies such as national electricity networks etc.* (4.7%), *the absence of active banks and insurance companies in REs* (3.9%), *the absence of proper international cooperation with the International REs Agency and World Bank* (3%), *the lack of infrastructure facilities* (2.8%), *the absence of sustainable energy and environmental policies* (2%), and *the absence of an appropriate structure for encouraging and support of REs use and development* (1.8%).

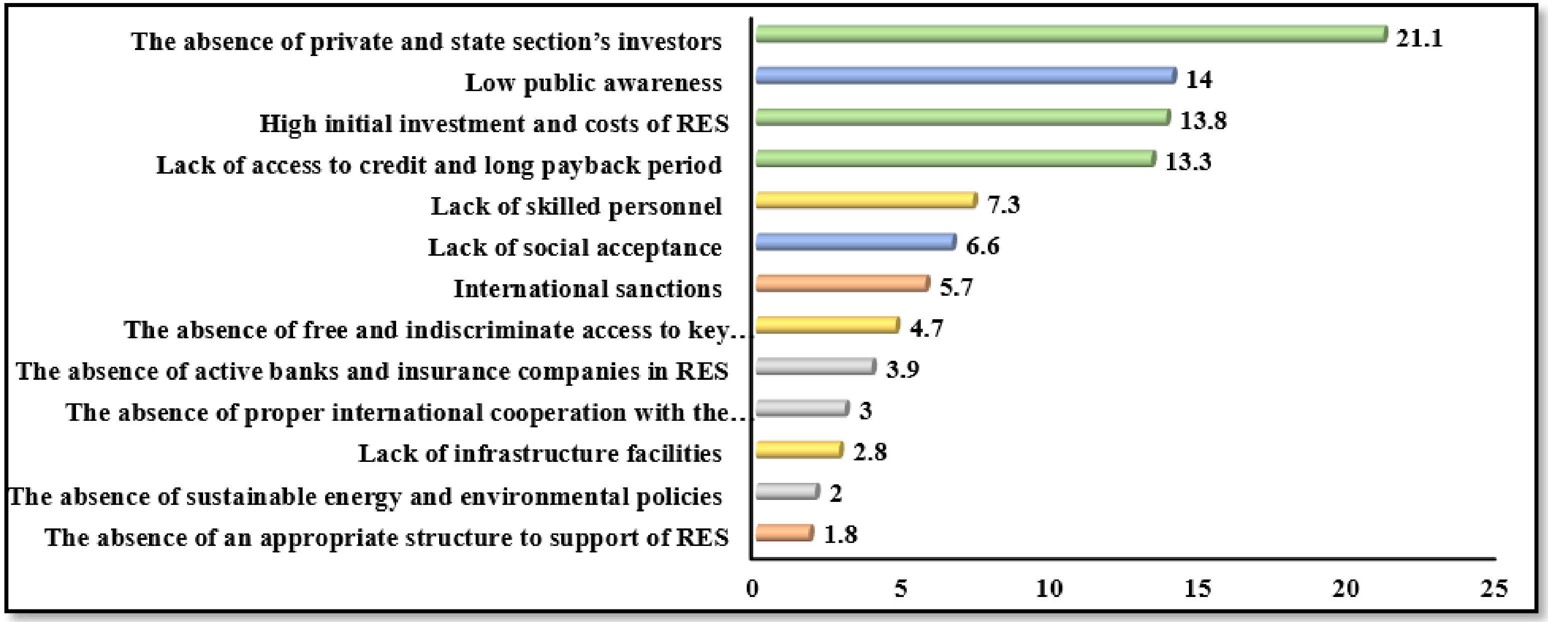


Figure 4.5. Global ranking of barriers

Moreover, by aggregating the weights throughout the hierarchy, the relative importance (composite priorities) of the intended alternatives based on the barriers was determined, which was reported in the appendix C.3. However, aggregated group results for identifying barriers to the development of the intended alternatives was drawn in Figure 4.6. According to this Figure, the top four barriers to the development of three investigated alternatives could be listed as:

- The absence of private and state section's investment.
- The lack of access to credit and a long pay-back period.
- High initial investment and cost of renewable technology (providing subsidy for fossil fuel).
- Low public awareness (in the social, cultural, and behavioral dimension) (Figure 4.7).

The relative importance of each criterion in hindering the development of each alternative was reported in appendix C.4.

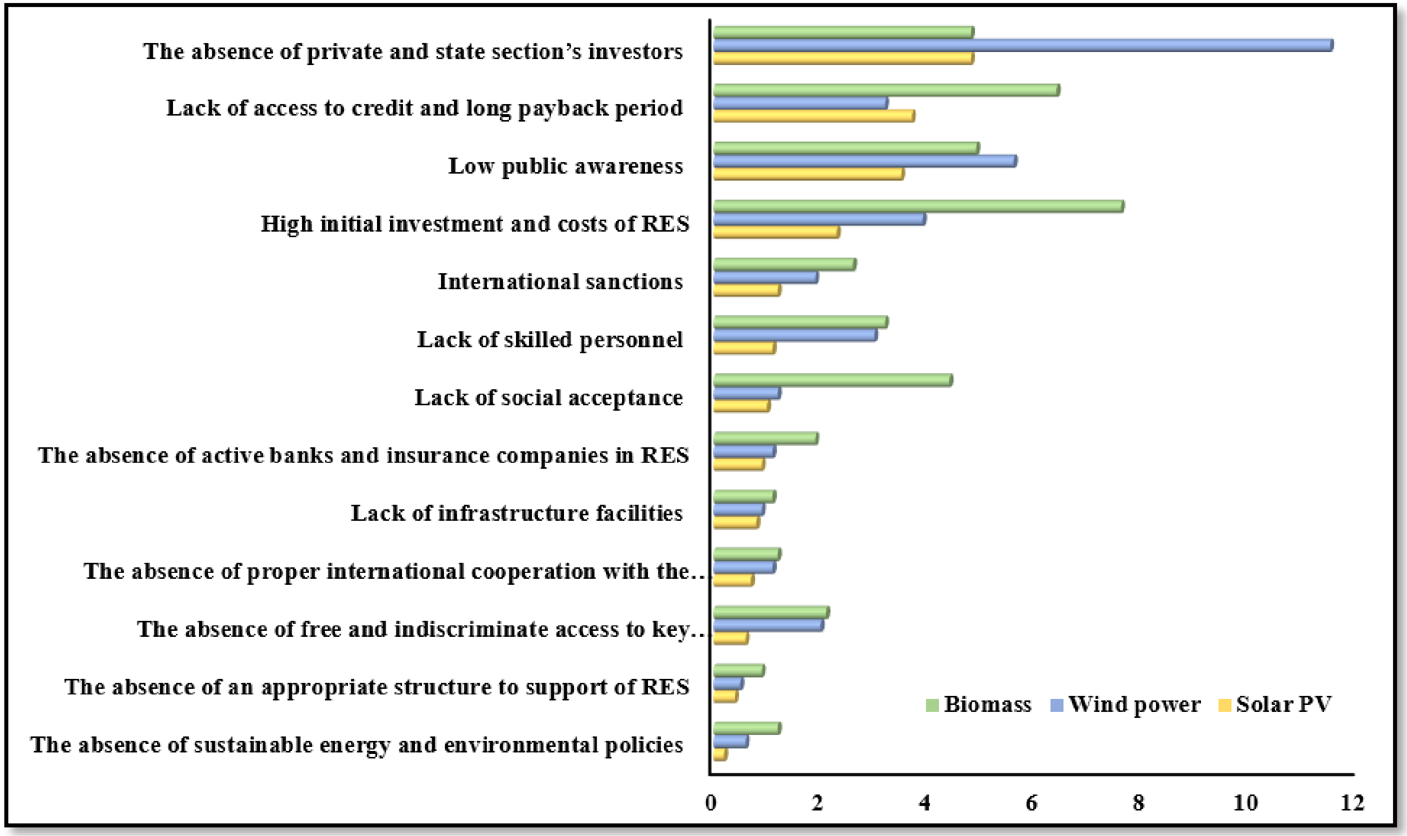


Figure 4.6. Aggregated group results

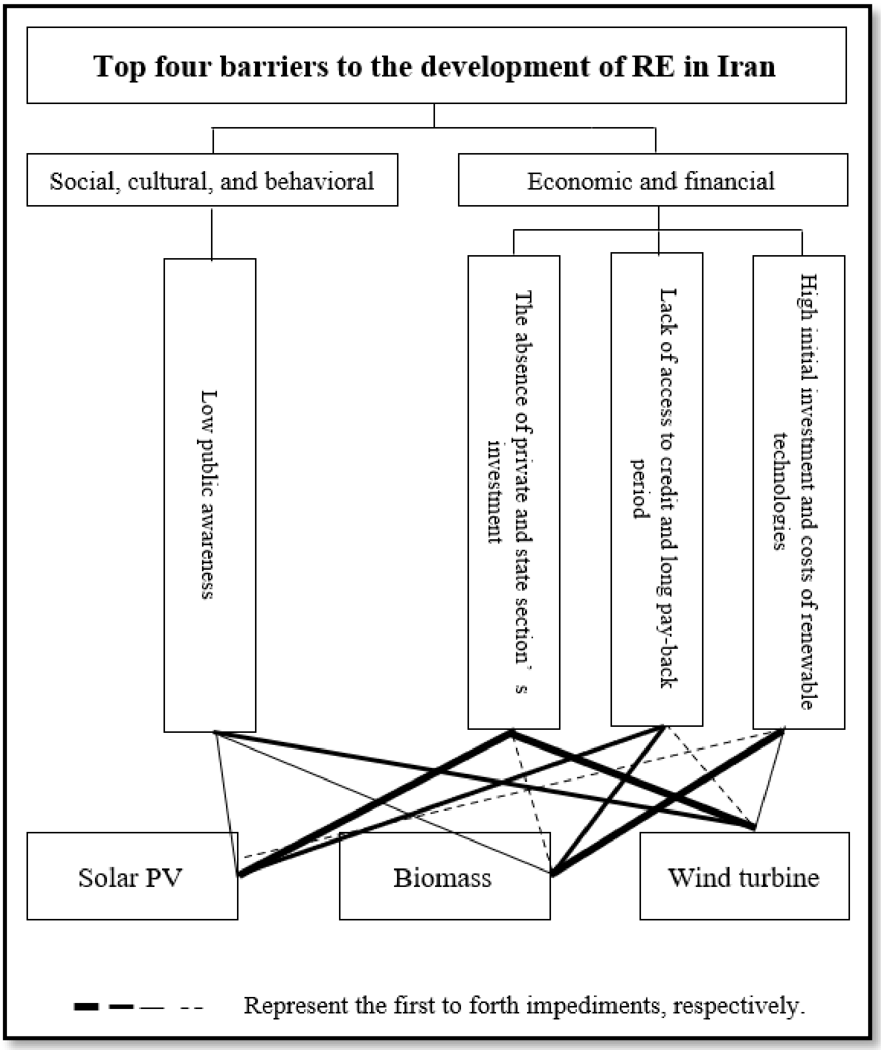
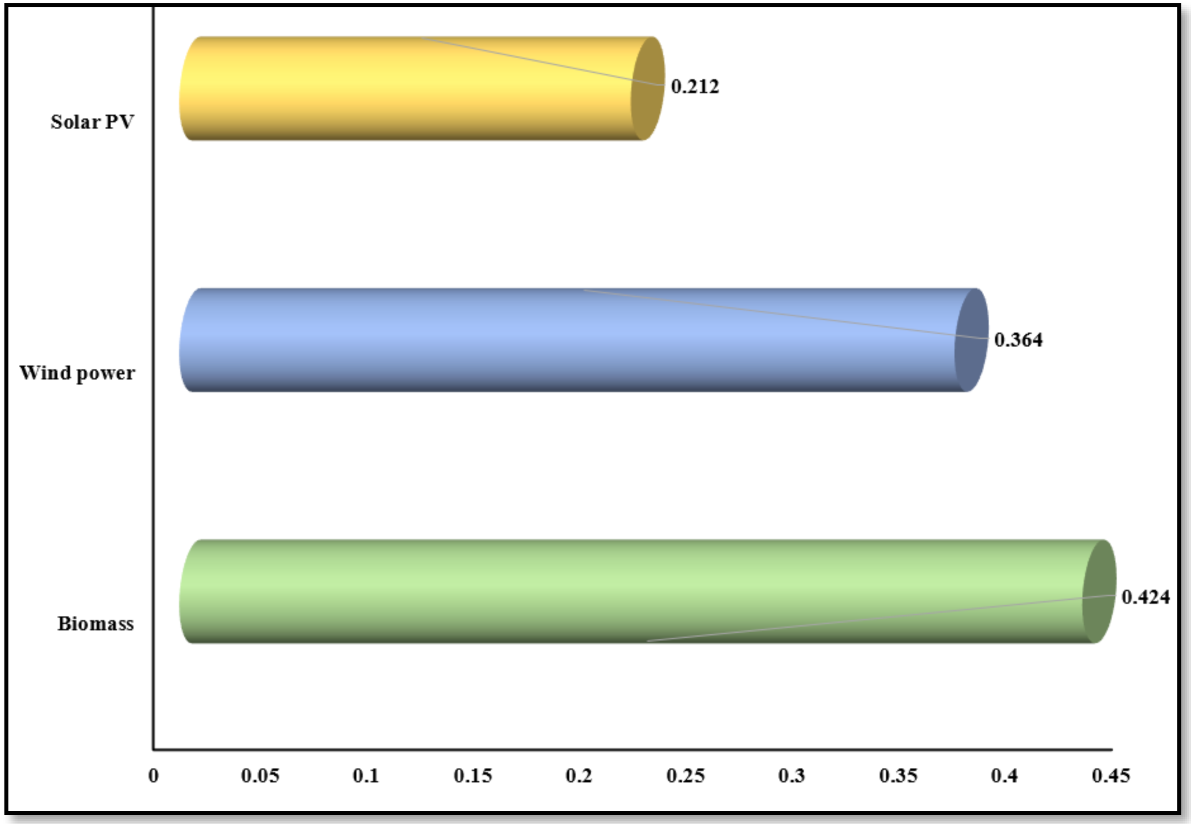


Figure 4.7. Top four barriers to the development of REs

Ultimately, the final synthesized results of alternatives concerning the goal were depicted in Figure 4.8. This Figure, demonstrated the fewer barriers to the development of solar PV (0.212) in Iran, followed by a wind power (0.364), and biomass (0.424).



Consistency Ratio (CR): 0.01

Figure 4.8. Ranking of alternatives

4.5.4. Sensitivity analysis

The weight of the main criteria determines the final priority of the alternatives. Consequently, the final ranking could be changed by the small shifts in relative importance. Moreover, as these weights are extremely personal and judgments-based, the ranking stability should be checked through assigning different criteria weights (C.-W. Chang et al., 2007). In this regard, the sensitivity of the specialist's decision and the reality of the results, the *dynamic sensitivity analysis* was performed using Export Choice 2000 second edition (Thomas Lorie Saaty, 1996). A rigorous revision of priority weight is recommended, when the ranking of alternatives is extremely sensitive to the small variations in the weight of criteria (C.-W. Chang et al., 2007).

Therefore, the impact of change in the priority weight of five main criteria on the alternative's rank was investigated in different scenarios. The first scenario was illustrated in Figure 4.9.

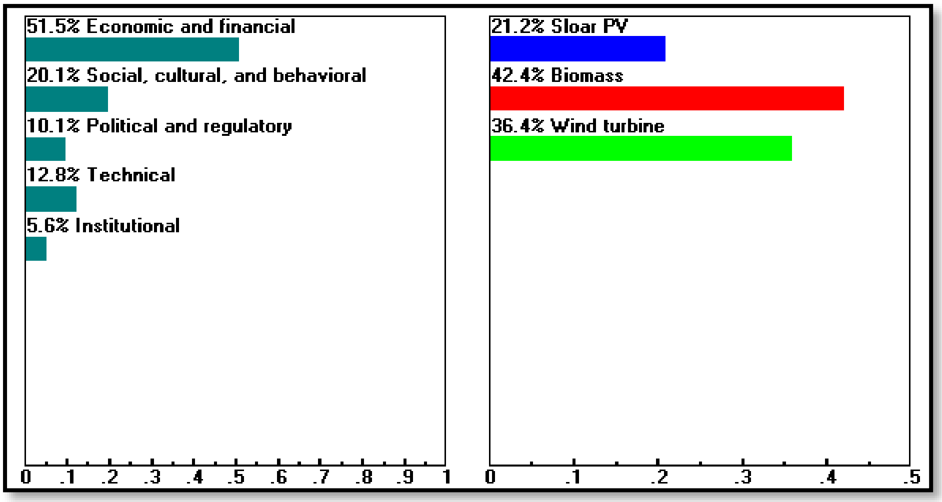


Figure 4.9. Base scenario

As mentioned earlier in the empirical finding, the economic and financial barrier (51.5%) is the most significant hindrance to the development of REs in Iran, followed by social, cultural, and behavioral barrier (20.1%), political and regulatory barrier (10.1%), technical (12.8%), and institutional (5.6%). Accordingly, the development of solar PV (21.2%) was detected to be faced with fewer limitations, followed by a wind power (36.4%), and biomass (42.4%). The results of a 20% increase and decrease in the main criteria (was depicted in Figure 4.10 to Figure 4.19.

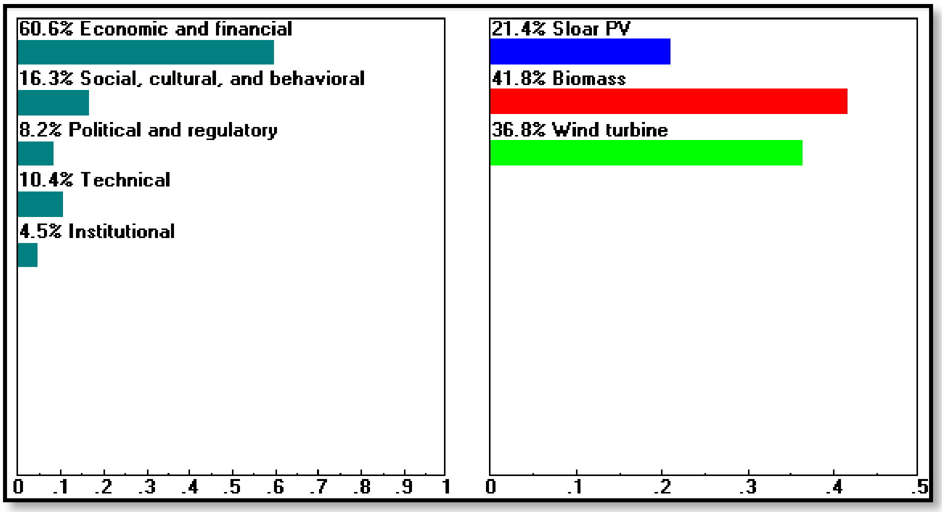


Figure 4.10. Dynamic sensitivity of alternatives when economic and financial dimension is increased by 20%

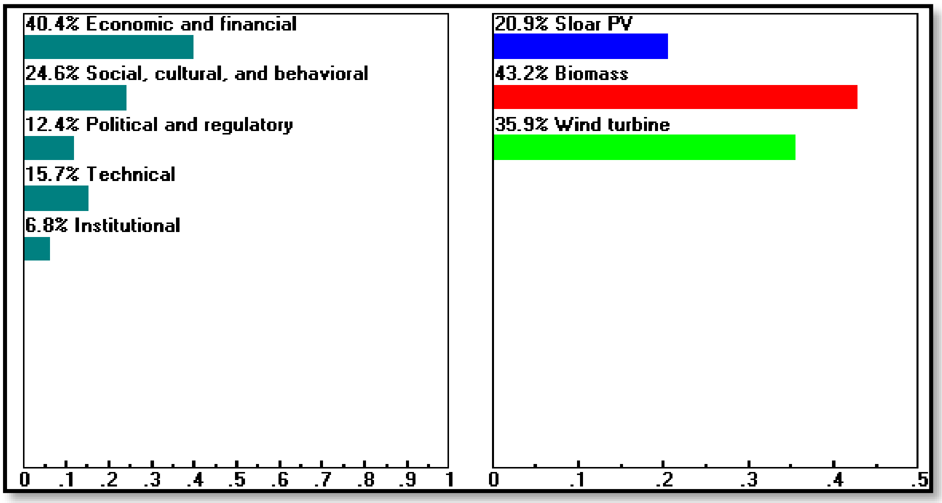


Figure 4.11. Dynamic sensitivity of alternatives when economic and financial dimension is decreased by 20%

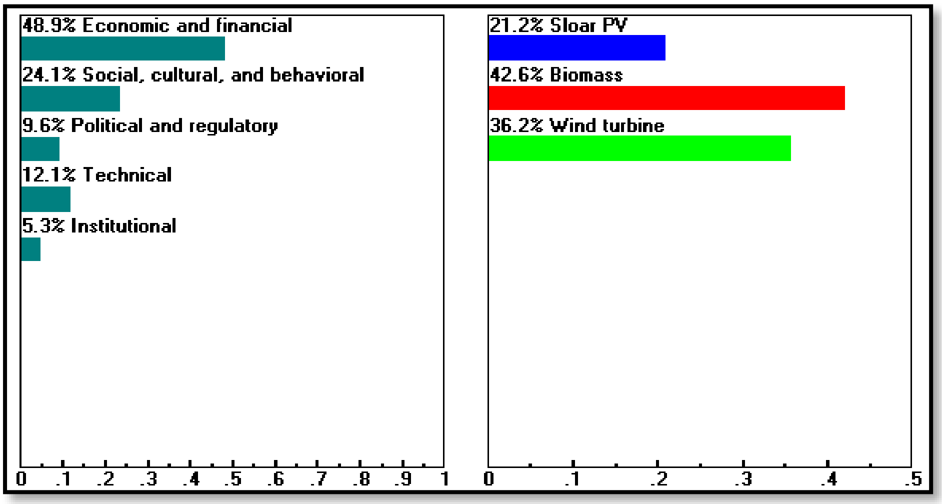


Figure 4.12. Dynamic sensitivity of alternatives when social, cultural, and behavioral dimension is increased by 20%

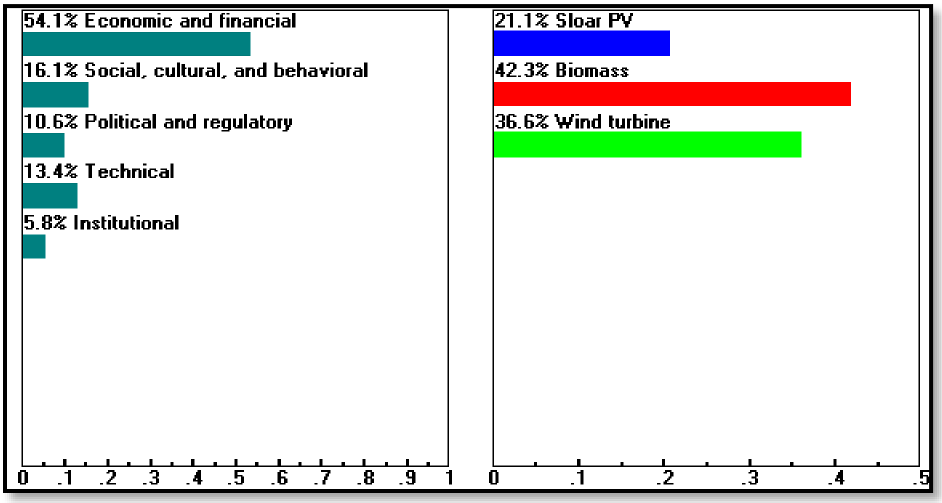


Figure 4.13. Dynamic sensitivity of alternatives when social, cultural, and behavioral dimension is decreased by 20%

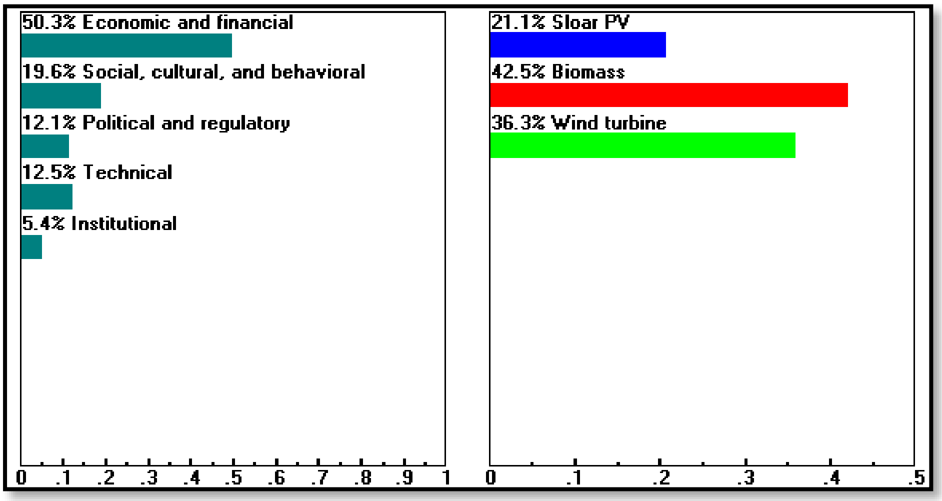


Figure 4.14. Dynamic sensitivity of alternatives when political and regulatory dimension is increased by 20%

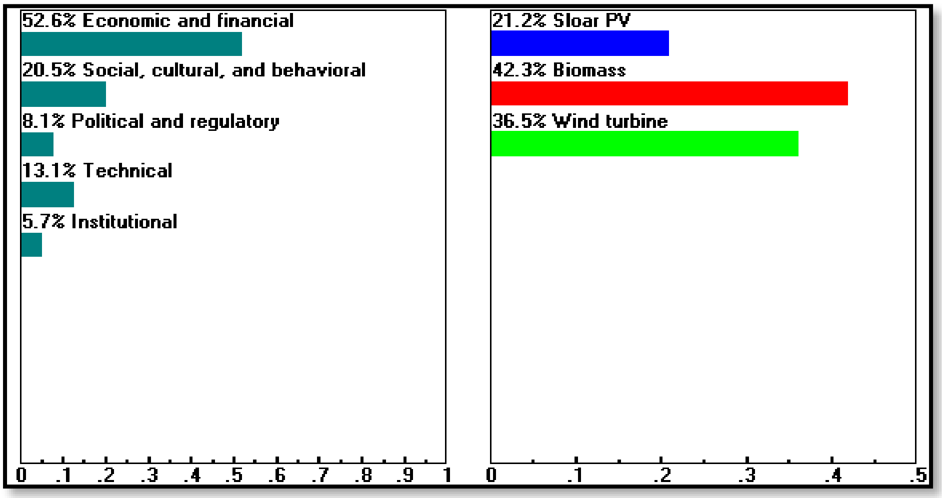


Figure 4.15. Dynamic sensitivity of alternatives when political and regulatory dimension is decreased by 20%

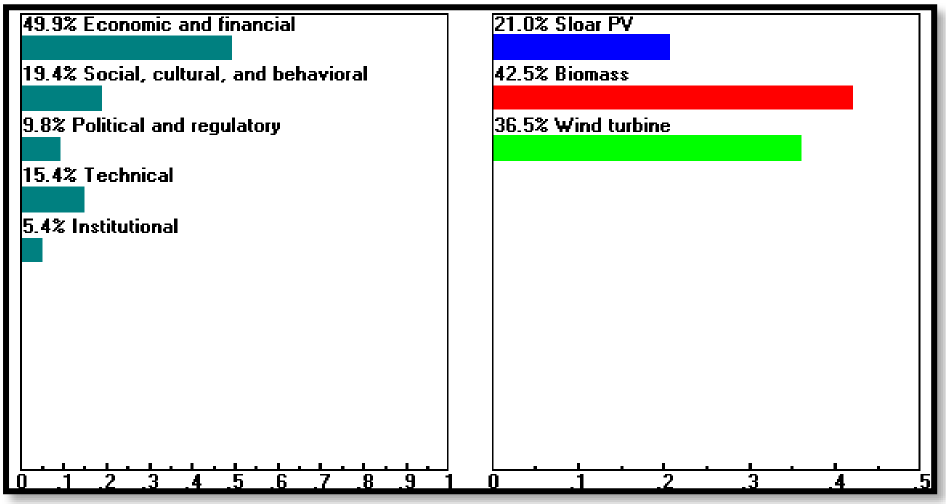


Figure 4.16. Dynamic sensitivity of alternatives when technical dimension is increased by 20%

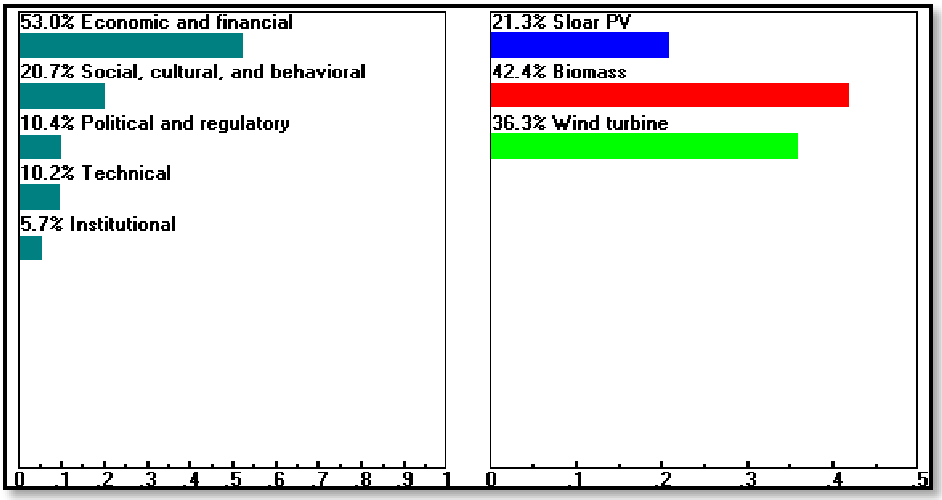


Figure 4.17. Dynamic sensitivity of alternatives when technical dimension is decreased by 20%

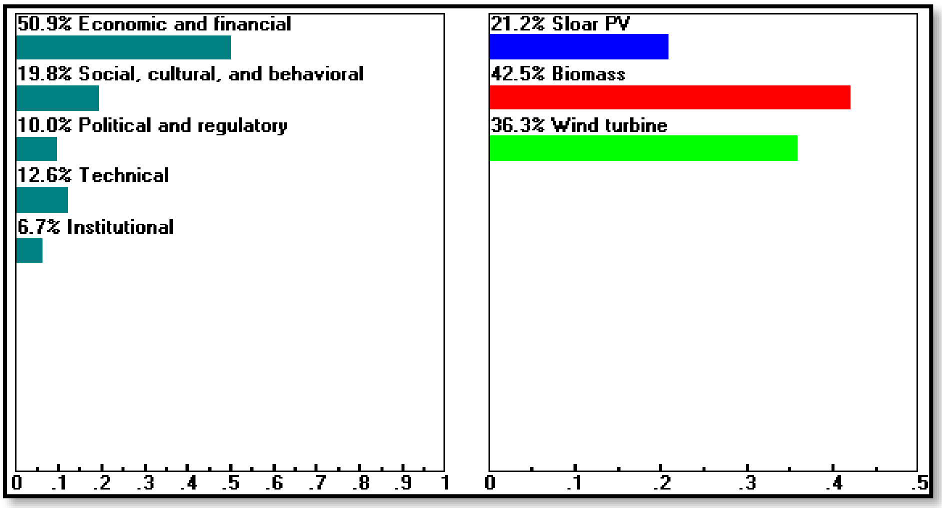


Figure 4.18. Dynamic sensitivity of alternatives when institutional dimension is increased by 20%

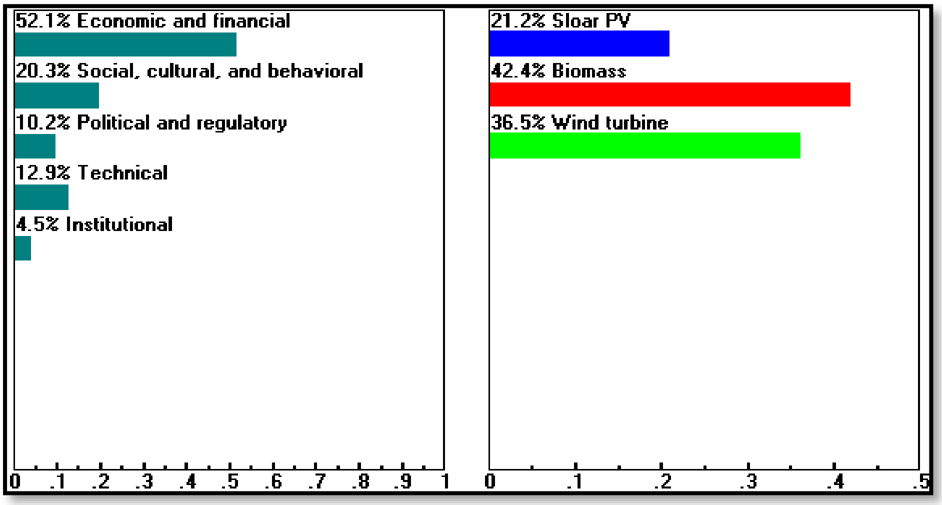


Figure 4.19. Dynamic sensitivity of alternatives when institutional dimension is decreased by 20%

The result of the sensitivity analysis confirmed the stability of alternatives. Indeed, the order of alternatives remained constant following changes (both increase and decrease) in the priority weight of the main criteria in all possible combinations. In sum, it could be concluded that the development of solar PV should be considered in the first step as the most preferred type of renewable energy, followed by a wind power, and biomass.

4.6. Limitation and future research

Although, the result of this research could provide the basic framework for the government, the policymakers, the managers, the private sector, and the executors involved in designing and formulating the REs projects in the developing countries like Iran, there are some limitations, which can be summarized as follows:

i. As this study only considered the impediments to the development path of RES in Iran from the supply side's point of view, future researches can incorporate demand-side expert's opinions to present different scenarios.

ii. Since this approach is the expert's judgment-based method, the number of specialists, the intended organization, and the questions can be adjusted in future researches to reduce the possible bias in the expert's opinion.

iii. Different MCDM can be employed to the same problem, and the obtained outcomes can be compared with the results of this study in future researches. For instance, to illustrate the uncertainty in the assessment of RES alternative, the Fuzzy model can be applied along with AHP.

4.7. Conclusions and recommendations

Increasing the share of REs in the energies mix has drawn the government and policymakers' attention because of their significant advantages in reducing the environmental issues, as well as reducing the high dependence on conventional fuels and in boosting the economic growth, especially in developing countries such as Iran.

The high cost of utilizing REs technologies, and the easy access to fossil fuel resources, has pushed the government's tendency towards conventional resources. However, optimizing the usage of REs, preserving the fossil fuels for the next generations, and enhancing the stability of the country's energy supply system require launching comprehensive planning for the specified period towards the exploitation of REs sources. However, several barriers have hindered the development path of this technology.

As stated earlier, Iran has enormous potential in REs, partly due to its strategic and geopolitical position. Therefore, unlike the previous studies, the main purpose of this study was to identify and rank the most cost-effective REs among three suitable alternatives, called solar PV, wind power, and biomass.

To this end, based on the massive literature review and from the experts ‘point of views, 13 impediments in the development path of REs have been identified and were categorized into five main groups as economic and financial; social, cultural, and behavioral; technical; political and regulatory; institutional. Due to the advantages of the AHP approach over the other MADM technique in the energy field, especially in investigating sustainable energy and technology-related problems, this model was employed.

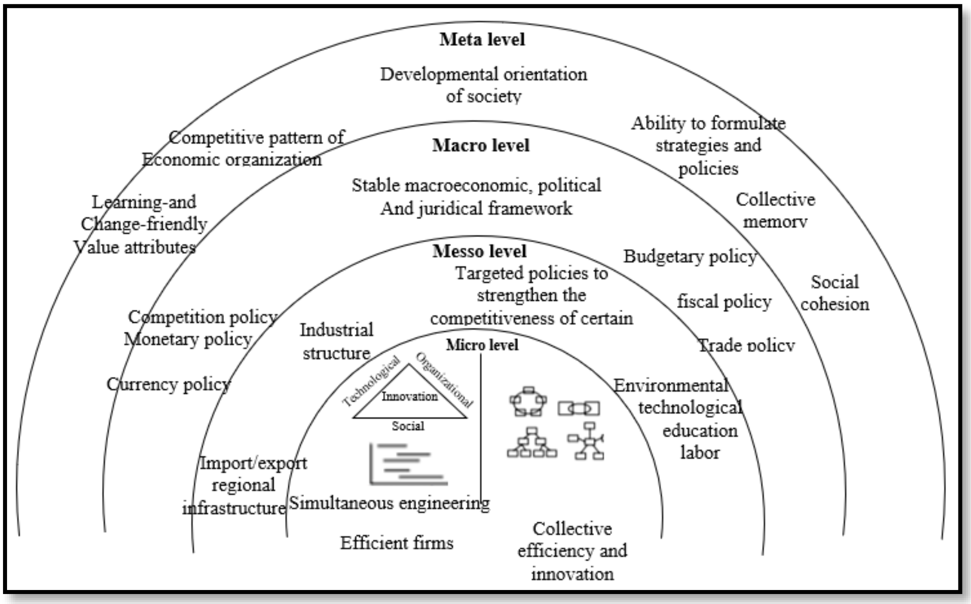
Accordingly, the pair-wise comparison questionnaire was designed and distributed among 30 experts from the Ministry of Energy, the Ministry of Petroleum, and the Petroleum University of Technology. After eliminating the inconsistent responses, 18 questionnaires have been retained for the final analysis. Since the relative importance (weight) of the main criteria is greatly based on the expert's judgments, the ranking stability (sensitivity) of alternatives regarding an infinitesimal variation in the priority weight of criteria must be checked. To this end, unlike the previous studies, the dynamic sensitivity analysis was conducted in this chapter.

From the results of ranking the main barriers, the economic and financial barriers (51.5%), followed by the social, cultural, and behavioural barriers (20.1%), the technical barriers (12.8%), the political and regulatory barriers (10.1%), and the Institutional barriers (5.6%) were identified as the main impediments of expanding REs in descending orders. Based on the results of the overall ranking of barriers, the top four impediments (62.4%) to the expansion of REs could be listed as follows:

1. The absence of private and state section's investment.
2. Low public awareness.
3. High initial investment cost and high costs of renewable technologies.
4. The lack of access to credit and the long payback period.

The final synthesized results of alternatives concerning the goal demonstrated fewer barriers to the development of solar PV, followed by wind power and biomass. This finding indicated that in the first stage of expanding renewable energy, the solar PV should be considered as the most preferred type of renewable energy, followed by wind power and biomass by the government and the policymakers in Iran. the aggregated group results for identifying barriers to the development of solar PV demonstrated that the lack of private and state sectors' interest in investing, the low access to credit and the long payback period, the low public awareness, and the high initial investment cost and high costs of renewable technologies are amongst top four obstacles. Therefore, overcoming the mentioned barriers should be placed in the priority. The stability of alternatives has been confirmed through conducting the sensitivity analysis. Indeed, the order of alternatives remained unchanged following changes (both increase and decrease) in the priority weight of the main criteria in all possible combinations.

Following the Systematic Competitiveness Model (see Figure 4.20), the target, strategy, and action plans to remove the barriers to the development of the applicable renewable energies (with emphasis on the solar PV) have been divided into four levels, called Micro, Messo, Macro, and Meta.



Source: (Meyer-Stamer, 2005)

Figure 4.20. Determinants of Systemic Competitiveness

i. **Micro level.** This level covers consumers, producers, and markets. Indeed, to create an advantage in the competitive market, companies introduce innovation and make efforts to increase their productivity. It's noteworthy to notice that the participation of influential companies to maintain their competitive endeavours and networks is also included in this level.

ii. **Meso level.** This level consists of interventions to help companies to create their competitive advantages by either the government or associations. These interventions consider market failure in several areas like finance, innovation, and technology, labour market, and skill development, business services, and so on.

iii. Macro level. This level constitutes the general framework conditions, economic policies, and institutions. The outcomes of the governments' activities such as property rights, the effectiveness of laws, and their implementation are evaluated.

iv. Meta level. This level addresses the slower variables, which could be divided into three elements as follows:

- The socio-cultural factors such as coherence, the structure of ambitions and awards, social capital.
- The political factors such as society's ability to be organized in such a way that can solve the problems effectively.
- The economic factors such as the openness of the economy, the relative importance of markets, and primary economic orientation (Cunningham, 2012).

The target, strategy, action plan, and authority in charge related to each level were illustrated in Tables 4.5. to 4.9.

Table 4.5. Strategy and action plan regarding Micro level

(Improvement of the business environment**)**

Strategy	**Action plan**	**Authority in charge**
Create an enabling environment for the investors		•IDRO •MOIMT •MOE
Reducing licensing and constructing capital cost of renewable power plants	Reviewing the required number of licenses and facilitate launching the single windows for investment licenses	MOE

Table 4.6. Strategy and action plan regarding Messo level

(strengthen supply and improve investment performance)

Strategy	**Action plan**	**Authority in charge**
Increasing the investment incentives to create a secure investment environment	Formulating an inclusive national energy master plan (strategic energy plan) toward managing the energy use to increase the energy security and energy efficiency using the REs technologies in short, medium-, and long-term horizon.	• MOE • MOP • PBO
	Adhering to the guaranteed purchase of renewable electricity by the investor Targeting financial incentive in "The Comprehensive document of establishing the mechanism of the retail electricity market in Iran" to absorb private sector capital	MOE
	• Granting interest-free loans to purchase equipment • Imposing taxes on pollution emissions	MOIMT
	Creating a framework for retail electricity by renewable power plants (and supplying in the energy exchange)	MOE
	Launching supportive package including: A. providing tax concessions, B. gradual fossil fuel price liberalization (to catch up with international level) C. reallocating financial resources from subsidy reform to invest in renewable sources, energy efficiency.	MOEAF
Reducing the relative cost of inputs	Providing soft loans at: A. preferential rate B. long term payback period C. interest holidays	MOIMT

Strategy	Action plan	Authority in charge
	Passing discounts on raw material prices used in the production REs generators.	MOP
	Promoting and facilitating the process of importing the required raw materials and equipment for REs	LOEIR
	Providing R&D investment incentives in REs production units through: A. Returning a portion of the Research and Development costs to the units B. Considering the research expenses as tax eligible costs (R&D)	• MOEAF • INTA
	Facilitating technology transfer from developed nations in the form of licensing, joint venture, Joint R&D, Strategic alliance, and so on.	LOEIR
Supporting labor force training & management	Enhancing the contribution of human capital in the renewable and EVs through: A. Launching vocational training courses B. Enhancing the role of triple helix model of innovation in REs sector through increasing a set of interactions between academia, industry and government	HCOTVSE

Table 4.7. Strategy and action plan regarding Messo level

(Stimulate domestic demand)

Strategy	Action plan	Authority in charge
Regulating fossil energy market	Establishing an independent regulatory body for the energy sector	•CC
Creating relative cost-effectiveness in REs consumption	Increasing the relative price in the fossil fuels market as the substitute market	•MOE •MOP

Strategy	Action plan	Authority in charge
Increasing the public tendency towards REs	• Providing education-related advertising and marketing, teaser campaigns • Holding specialized exhibitions (fairs)	• MOED • IRIB •IIECO
Guarantee demand for RES (solar PV)	• Setting a minimum target for RES consumption with an emphasis on solar PV	• MOE

Table 4.8. Strategy and action plan regarding Macro level

(economic & structural reform)

Strategy	Action plan	Authority in charge
Providing better environment and to support investment in the REs and EV's sector.	Restructuring the economic structure of interest rate	•SNSC
Controlling and targeting inflation.	Facilitate justifying the innovation-based projects in the energy and transportation sectors economically and to retain the purchasing power	•CBIIR
Proper planning regarding the export and import in these markets	• Pursuing Exchange rate-based stabilization	•CBIIR

Table 4.9. Strategy and action plan regarding Meta level

(expanding market)

strategy	Action plan	Authority in charge
Culture-building and constructing the ethical business culture	Implementing the Awareness and Training Programs in social media	• DOEIRIM • MOE
	Holding workshops, seminars, and conferences	COC

strategy	**Action plan**	**Authority in charge**
Reviewing the political diplomacy	Reviewing the policies of the resistance economy declared by the Expediency Discernment Council.	MOFA
	Structuring and designing the new policy to perform a structural transformation in trade, which needs the cabinet approval	• MOIMT • MOFA

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Annexes

A. Environmental Impact of Transportation and Power Sectors: related studies

Table A.1. Summary of empirical studies on energy-CO2 nexus

Authors	Data	Variables	Methodology	Impact on CO_2 emissions	
				RE	Other Variables
Panel I. REs-CO_2 Emissions Nexus Studies					
(Jebli & Youssef, 2015)	Tunisia/ 1980-2010	CO_2, Y, Y^2, RE, NRE, TI	ARDL, VECM Granger Causality	(-)	LR: NRE, TI: (+)
(Ben Jebli et al., 2015)	SSA-24/ 1980-2010	CO_2, Y, Y^2, RE, RPEX, RPIM	Panel, FMOLS, OLS, Granger Causality	(-)	RPEX: (+); RPIM: (-)
(Bölük & Mert, 2015)	Turkey/ 1961-2101	CO_2, Y, Y^2, EPR	ARDL	(-)	
(Al-Mulali et al., 2016)	LACC/ 1980-201	CO_2, Y, Y^2, RE, FD	FMOLS, VECM Granger Causality	(×)	FD: (-)
(Al-Mulali et al., 2015)	Vietnam/ 1981-2011	CO_2, Y, ELF, ELR, K, L, EX, IM	ARDL	(×)	ELF, IM, K: (+); L:(-); EX:(×)
(Dogan & Seker, 2016)	EU-15/ 1981-2012	CO_2, Y, Y^2, RE, NRE, TO	Dumitrescue- Hurlin panel Granger causality	(-)	NRE: (+); TO: (-)
(Bilgili et al., 2016)	OECD-17/ 1977-2010	CO_2, Y, Y^2, RE	FMOLS, DOLS	(-)	
(Al-Mulali et al., 2016)	OECD-25/ 1980-2010	CO_2, Y, Y^2, RE, NRE, TI	FMOLS, DOLS	(-)	NRE: (+); TI: (-)
(Sugiawan & Managi, 2016)	Indonesia/ 1971-2010	CO_2, Y, EPR, EC,	ARDL	(-)	EC: (+); TFP: (-)
(Al-Mulali & Ozturk, 2016)	Advanced countries- 27/ 1990-2012	CO_2, Y, RE, NRE, TO, URB, PC	Panel FMOLS	(-)	NRE, URB: (+); TO, PC: (-)
(Danish et al., 2017)	Pakistan/ 1970-2012	CO_2, Y, RE, NRE	ARDL, ECM	(-)	NRE: (+)

(Liu et al., 2017)	ASEAN-4/ 1970-2013	CO_2, Y, RE, NRE, AGR	Panel VECM Granger Causality	(-)	NRE: (+); AGR: (-)
(Zoundi, 2017)	African Countries-25/ 1980-2012	CO_2, Y^2, Y, PPEC, ELR	Panel Cointegration	(-)	PPEC, POP: (+)
(Dong et al., 2017)	BRICS/ 1985-2016	CO_2, Y^2, Y, PNG, RE	Panel VECM causality	(-)	PNG: (-)
(Dong et al., 2018)	China/ 1965-2016	CO_2, Y, PNG, RE	ARDL, VECM Granger causality	(-)	PNG: (-)
(Pata, 2018)	Turkey/ 1974-2014	CO_2, Y, RE, HYP, FD, AEC, URB	ARDL, GH & HJ co-integration, FMOLS & CCR	(×)	FD, URB: (+); AEC, HYP: (×)
(Zambrano-Monserrate et al., 2018)	Peru/ 1980-2011	CO_2, Y, GAS, POIL, RE	ARDL, VECM Granger Causality	(-)	GAS, POIL: (+)
(Sinha & Shahbaz, 2018)	India/ 1971-2015	CO_2, Y, Y^2, RE, TR, TFP, EC, EPR	ARDL	(-)	TR: (-)
(Gill et al., 2018)	Malaysia/ 1970-2011	CO_2, Y, Y^2, REP	ARDL	(-)	
(Y. Chen et al., 2019)	China/ 1980-2014	CO_2, Y, Y^2, RE, NRE, T	ARDL, VECM Granger Causality	(-)	NRE: (+); T: (-)
(Yao et al., 2019)	17 developing & developed countries, six geo-economic regions/ 1990-2014	CO_2, Y, Y^2, RE	FMOLS, DOLS	(-)	
(Lau et al., 2019)	OECD-18/ 1995-2015	CO_2, Y, Y^2, NUC, ELN, TO	Panel GMM, FMOLS	(-)	NUC, TO: (-); ELN: (+)
Panel II. Energy-CO_2 Emissions Nexus Studies in Iran					
(Saboori & Soleymani, 2011)	Iran/ 1997-2007	CO_2, Y, Y^2, EC	ARDL		EC: (+)
(Safdari et al., 2013)	Iran/ 1971-2008	CO_2, Y, POP, URB, EC	Johansen-Juselius, ECM, Engel-Granger		Y, EC, SHARE, POP: (+)
(Ozcan, 2013)	Middle East-12 (Iran)/ 1990-2008	CO_2, Y, Y^2, EC	Panel, FMOLS		EC: (+)

(Apergis & Ozturk, 2015)	Asian-14 (Iran)/ 1990-2011	CO_2, Y, PD, LD, SHARE, QI	Panel GMM, FMOLS, DOLS, PMGE, MG		PD, SHARE, LD: (+)
(Amadeh & Kafi, 2015)	Iran/ 1971-2009	CO_2, Y, EC	Johansson Juselius, VAR, VECM		EC, Y: (+)
(Taghavee et al., 2016)	Iran/ 1974-2012	CO_2, Y, EC, TO, FD, L, K, URB	simultaneous equations system, 3SLS		EC, URB, TO, L, K: (+); FD: (-)
(Al-Mulali et al., 2016)	Seven regions (Iran)/ 1980-2010	CO_2, Y, URB, TO, FD, RE	Panel, DOLS, VECM Granger Causality	CEE, WE, EAP, SA, and the Americas: (-) MENA, SSA: (×)	
(Sinha et al., 2017)	N-11 countries (Iran)/ 1990-2014	CO_2, Y, Y^2, RE, L, HDI, TO, NRE, BE, GCF, URB	GMM	(-)	BE, NRE, URB: (+); TO: (-)
(Sarkodie & Strezov, 2019)	Developing countries-5 (Iran)/ 1982-2016	CO_2, Y, FDI, GHG, ENE	Panel, Quantile regression, Driscoll-Kraay panel regression		FDI, ENE: (+)

B. Modelling Consumer's Purchasing Intention for Electric Vehicles in Four Megacities of Iran

Dear respondents:

Thanks for participating in this survey, which is conducted to get a Ph.D. degree entitled "Green-Growth Strategy in Iran: What Role Energy Mix & Transportation Sectors Can Play?''. This thesis is undertaken by **Bahareh Oryani**, the Department of Technology Management Economics Policy Program (TEMEP) at Seoul National University, under the guidance of Professor **Yoonmo Koo**.

To overcome current environmental problems, which is partially caused by the transportation system (about 26%), high share of fossil fuels in energy mix (about 91%), and electricity generation (81%), the government and policy-makers of Iran have taken some measures to shift away from conventional-based vehicles (Internal Combustion Engine) toward Alternative Fuel Vehicles (AFVs), such as Hybrid Electric Vehicles (HEVs) and Battery Electric Vehicles (BEVs). HEV is mainly driven by the Internal Combustion Engine (ICEV) and electric motor assists ICEV in acceleration. The battery for powering an electric motor is charged internally by ICE, while the BEV is driven by an electric motor powered by an on-board battery (Q. Zhang et al., 2018). Given the importance of evaluating the market potential before launching new products, this survey intends to investigate the consumer's purchasing intention to Eclectic Vehicles in four major cities of Iran (Tehran, Mashhad, Shiraz, and Isfahan). In this regard, DENA Sedan, which is powered by gasoline is considered as a base and is consumers are asked to state their willingness to pay for its hybrid and an electric version. Furthermore, Due to lack of market penetration, the Stated Preference (SP) approach is employed. In this method, the most important attributes and the associated levels are considered. The considered attributes and levels are illustrated in the table B.1.

Table B.1. Attributes and Levels

Attribute	Vehicle A	Vehicle B	Vehicle C
Fuel type	ICEV (Gasoline)	HEV	BEV
Purchase price (USD)	1. 8,000 2. 12,000 3. 16,000	1. 12,000 2. 16,000 3. 20,000	1. 16,000 2. 20,000 3. 25,000
Fuel cost per 100 Km (USD)	1. 1 2. 1.5 3. 2 4. 2.5	1. 1 2. 1.5 3. 2 4. 2.5	1. 1 2. 1.5 3. 2 4. 2.5
The availability of charging station (% of current gasoline stations)	100	100	1. 10 2. 40 3. 70
Non-financial policy incentives	No incentive	No incentive	1. No incentive 2. Access to Bus Rapid Transit (BRT) lanes 3. No restricted driving per plate number 4. Bothe of them

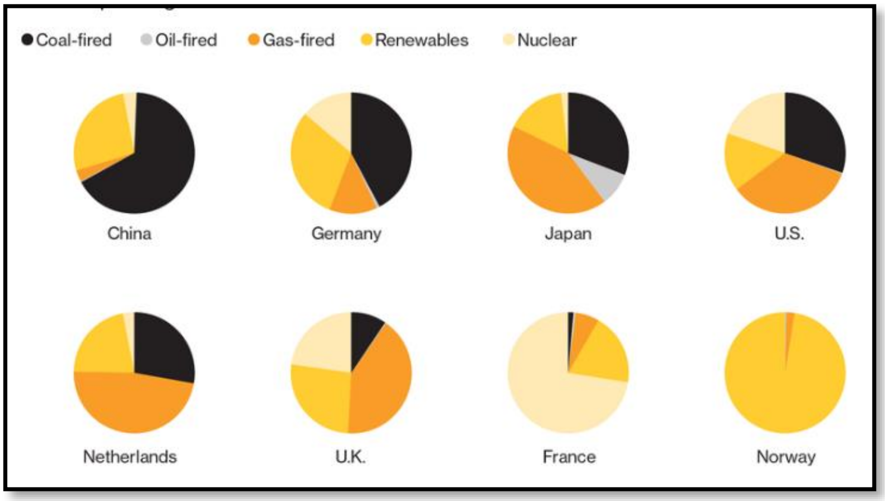
Some of advantage and disadvantage of EV, which you can consider in choosing them, could be listed as follows:

Advantages: faster acceleration, higher energy efficiency, lower operational cost, environmental image; reduced fueling costs; and technological innovation. Therefore, EVs have been recognized as a promising alternative to ICEV vehicles with good prospects (F. He et al., 2013).

Disadvantages: high purchasing price, limited driving range per charge, long charging time, and lack of charging infrastructures (Q. Zhang et al., 2018).

B.1. Assumption for group A

It is worthwhile to say that EVs are not emission-free. As you know, EV runs on electricity, which comes from a mix of emissions-intensive fossil fuels, nuclear, to a lesser extent, renewable energies. Therefore, the emissions caused by this type of vehicle highly depends on the sources of the electricity, on the efficiency of the vehicle (Rachael Nealer, 2015), and on the energy wasted in the charging process. To gain a better understanding, electricity generation by fuels in selected counties is depicted in figure B.1.1.



Note: Renewables include geothermal, solar, wind, biomass and waste, large and small hydro sources: **Source**: Bloomberg New Energy Finance

Figure B.1.1. Electricity Generation by Fuels in selected countries (%)

As illustrated in figure B.1.1, in some countries like Norway electricity is generated from renewables (particularly from hydropower plants) and therefore, EV is a symbol of true zero emissions vehicle. While, in China, the world's biggest EV markets, the electricity generation relies on emissions-intensive fossil fuels, especially coal-fired plant, which reduced the role of EV in environmental concerns. Based on the 'BP statistical Reviews of World Energy' in 2017, about 80.7% of total electricity in Iran was generated from Natural Gas followed by oil (11.3%), therefore changing the energy mix towards REs and increasing the share of renewable electricity in the form of EVs will lead to a decrease in CO_2 emissions caused by transportation sector.

B.2. Assumption for groups B

Even though, about 92% of electricity in Iran is currently generated by fossil fuels, let us assume that electricity for EV charge will be generated by renewably energy only. That means, there is no CO2 and other pollutant emissions while producing and using electricity for EV charge.

B.3. Choice cards for groups A

Suppose that EVs including HEV and BEV has penetrated in the market and there are different attributes and levels (has been shown in the form of card), which you can consider in making the decision.

Before responding to the questions, please keep in mind that:

1. All Vehicle alternatives (Vehicle A-C) suggested are a sedan (1645 cc)

2. Assume that all the other attributes, besides the five proposed here, remain the same.

Q1. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	**Vehicle B**	**Vehicle C**
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	8,000	12,000	16,000
Fuel cost per 100 Km (USD)	1	1.5	2
The availability of charging station (% of current gasoline stations)	100	100	70
Non-financial policy incentives	No incentive	No incentive	No incentive
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q2. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	**Vehicle B**	**Vehicle C**
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	16,000	12,000	20,000
Fuel cost per 100 Km (USD)	2.5	1	1.5
The availability of charging station (%of current gasoline stations)	100	100	10
Non-financial policy incentives	No incentive	No incentive	Access to BRT lanes
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q3. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	Vehicle B	Vehicle C
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	12,000	20,000	25,000
Fuel cost per 100 Km (USD)	1	1.5	2.5
The availability of charging station (% of current gasoline stations)	100	100	40
Non-financial policy incentives	No incentive	No incentive	No restricted driving per plate number
A. Choose the most preferred vehicle			○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q4. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	Vehicle B	Vehicle C
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	16,000	12,000	16,000
Fuel cost per 100 Km (USD)	1.5	2.5	1
The availability of charging station (% of current gasoline stations)	100	100	10
Non-financial policy incentives	No incentive	No incentive	Access to BRT lanes and no restricted driving per plate number
A. Choose the most preferred vehicle			○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q5. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	Vehicle B	Vehicle C
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	12,000	16,000	25,000
Fuel cost per 100 Km (USD)	2	2	2.5
The availability of charging station (% of current gasoline stations)	100	100	40
Non-financial policy incentives	No incentive	No incentive	No incentive
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q6. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	Vehicle B	Vehicle C
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	8,000	16,000	20,000
Fuel cost per 100 Km (USD)	1	2.5	2
The availability of charging station (% of current gasoline stations)	100	100	10
Non-financial policy incentives	No incentive	No incentive	No incentive
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q7. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	**Vehicle B**	**Vehicle C**
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	8,000	12,000	25,000
Fuel cost per 100 Km (USD)	2	1	2
The availability of charging station (% of current gasoline stations)	100	100	10
Non-financial policy incentives	No incentive	No incentive	No restricted driving per plate number
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q8. Please choose the most preferred vehicles among three hypothetical options provided below.

	Vehicle A	**Vehicle B**	**Vehicle C**
Fuel type	ICEV	HEV	BEV
Purchase price (USD)	12,000	20,000	16,000
Fuel cost per 100 Km (USD)	2	1.5	1
The availability of charging station (% of current gasoline stations)	100	100	40
Non-financial policy incentives	No incentive	No incentive	Access to BRT lanes
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

Q9. Please choose the most preferred vehicles among three hypothetical options provided below (trap question).

	Vehicle A	**Vehicle B**	**Vehicle C**
Fuel type	HEV	BEV	ICEV
Purchase price (USD)	12,000	16,000	80,000
Fuel cost per 100 Km (USD)	1.5	2	1
The availability of charging station (% of current gasoline stations)	100	70	100
Non-financial policy incentives	No incentive	No incentive	No incentive
A. Choose the most preferred vehicle	○	○	○

B. Are you willing to purchase the above selected car within 3 years?

Yes □ No □

B.4. Common parts for two groups

B.4.1. Respondent Demographic Information

1. Where do you live?	………………………….
2. What metropolitan region do you live?	………………………….
3. How old are you?	………………………….
4. What is your gender?	………………………….
5. What is the highest level of formal education you have completed?	………………………….
6. What is your occupation?	………………………….
7. What is your contact number?	…………………………
8. What is the approximate monthly cost of all members of your household?	……………………... ($)
9. Including yourself, how many people currently live in your household?	…………………………
10. How many children do you have in your household?	………………... (person)
11. How many years do you have car use experience?	…………………(years)
12. How many driving licenses do your household have?	…………………………
13. How much have you paid for driving cost (including fuel cost, maintenance, parking, insurance, etc.) last year?	……………………...($)
14. Do you have any plan to buy new vehicle in the coming 5 years?	………………………....
15. How many cars do your household own?	…………………….......

16. What is the maximum price you are willing to pay for a hybrid vehicle? ……………………...($)

17. What is the maximum price you are willing to pay for an electric vehicle? ……………………...($)

18. Vehicle specifications:

Car type	Vehicle model	Fuel type	fuel cost per KM	Driving distance in last year (Km)	Purchase Price (1,000 $)	Purchase year
Main		Gasoline □ Hybrid □				
Secondary		Gasoline □ Hybrid □				

I would like to give some bonus to participants randomly, write down your contact number, please.

B.4.2. Respondent Psychological Information

Please answer the following sentences according to your opinion (1: strongly disagree; 2: disagree; 3: neutral; 4: agree; 5: strongly agree).

		Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Normative Influence	When purchasing products, I usually purchase the brands that I think others will approve it	1	2	3	4	5
	If people can see me using a product, I often purchase the brand they expect me to purchase	1	2	3	4	5
	If I want to be like someone, I often try to get the same brands that they buy (Bearden et al., 1989)	1	2	3	4	5
Face perspective	Sometimes, I buy a product because my friends do so	1	2	3	4	5
	Name-brand purchase is a good way to recognize some people from others	1	2	3	4	5
	Name products and brand purchases can bring me a sense of prestige (Bao et al., 2003)	1	2	3	4	5
Risk aversion	I am cautious in trying innovative/new products	1	2	3	4	5
	I would rather stick with a brand I usually buy than try something I am not very sure of	1	2	3	4	5
Perceived symbolic meanings of car ownership	Car-ownership is a symbol of wealth status	1	2	3	4	5
	Car-ownership is a symbol of convenience status	1	2	3	4	5
	Car-ownership is a symbol of comfort	1	2	3	4	5
	Car-ownership is a symbol of freedom (XUE et al., 2013)	1	2	3	4	5

Thanks for your time and participate in this survey

C. Barriers to the Development of REs Technologies: Iranian Perspective

Dear respondents:

Thanks for participating in this survey, which is conducted to get a Ph.D. degree entitled "Green-Growth Strategy in Iran: What Role Energy Mix & Transportation Sectors Can Play?" This thesis is undertaken by **Bahareh Oryani**, the Department of Technology Management Economics Policy Program (TEMEP) at Seoul National University, under the guidance of Professor **Yoonmo Koo**.

This questionnaire is conducted to collect the specialist's opinion on the key barriers that hinder the development path of REs technologies in Iran. In this respect, five main criteria (20 sub-criteria) have been identified, and the Analytical Hierarchy Process model has been employed to prioritize them. Therefore, the specialists have asked to answer the pair-wise questions to compare relative importance of the main and sub-criteria. The hierarchical structure of the barriers to the development of REs technologies is shown in Figure C.1. As illustrated in Figure, the first level of the AHP method starts with the final goal of the research. The main criteria and sub-criteria that should be evaluated are placed in the second and third levels, respectively.

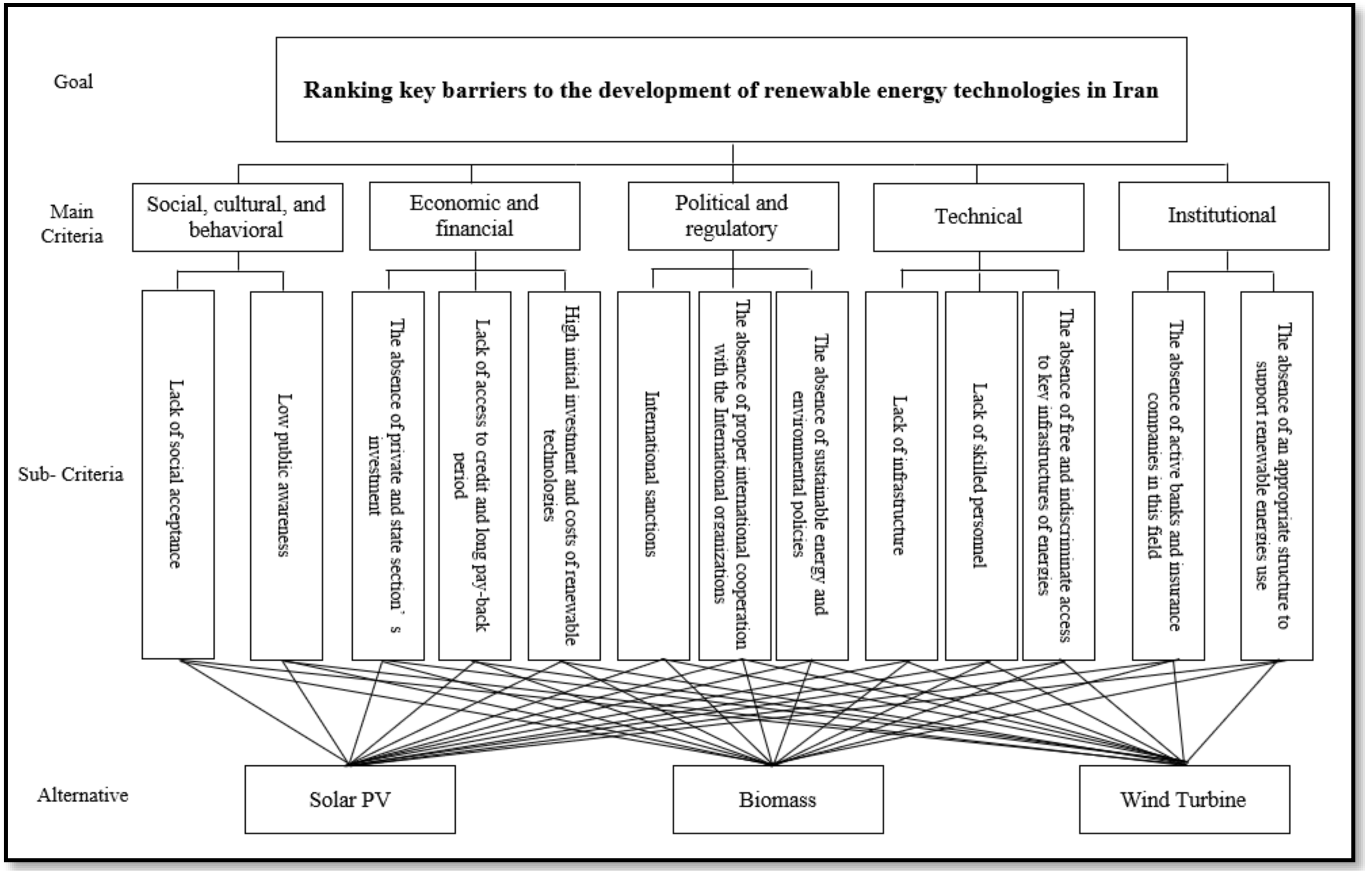


Figure C.1.1. Hierarchical structure of the barriers to the development of REs in Iran

C.1. Guideline to fill the questionnaire up

Selecting numerical scales for pair-wise comparisons were presented in Table C.1.1.

Table C.1.1. Selecting numerical scales for pair-wise comparisons

Explanation	Numeric scale
If option A and B have the same importance	1
If option A is moderately more important than option B	3
If option A is strongly more important than option B	5
If option A is very strongly more important than option B	7
If option A is extremely more important than option	9
Choose even numbers for intermediate evaluation	2, 4, 6, 8

How to do pair-wise comparison? An empirical example

According to the scales that have been shown in Table 2, please select the relative weight of your chosen criteria.

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Economic & financial	9	8	**7**	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Technical

Option A (economic and financial barriers) is a strongly important barriers to the development of RE compared to option B (technical barriers)

Option A (economic and financial barriers) and option B (technical barriers) are equally important barriers to the development of REs.

C.1.1. Main Barriers to the development of REs in Iran

Please rank the following main criteria in order of importance (Table C.1.2).

Table C.1.2. The rank of the importance of main criteria

Criteria	Rank
Economic & financial (EF)	( )
Cultural, social, and Behavioral (CSB)	( )
Political and regulatory (PR)	( )
Technical (Tech)	( )
Institutional (Inst)	( )

According to the identified criteria and using 1 to 9 scales (in which nine indicates the extremely important, and one shows the equal important), please select the relative importance of option "A" (in the left column) with respect to the option "B" (in the right column).

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
EF	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSB
EF	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PR
EF	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Tech
EF	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inst
CSB	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PR
CSB	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Tech
CSB	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inst
PR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Tech
PR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inst
Tech	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inst

Please rank the sub-criteria of economic and financial barriers in order of importance (Table C.1.3).

Table C.1.3. The rank of the importance of economic and financial sub-criteria barriers

Criteria	**Rank**
The absence of private and state section's investment	( )
Lack of access to credit and long payback period	( )
High initial investment (uneconomical development of solar and wind power station) and high costs of renewable technologies (providing subsidy for fossil fuel)	( )

According to the identified sub-criteria of economic and financial barriers, and using 1 to 9 scales (in which nine indicates the extremely important, and one shows the equal important), please select the relative importance of option "A" (in the left column) to the option "B" (in the right column).

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
The absence of private and state section’s investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of access to credit and long payback period
The absence of private and state section’s investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High initial investment and high costs of renewable technologies (providing subsidy for fossil fuel)
Lack of access to credit and long payback period	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High initial investment and high costs of renewable technologies (providing subsidy for fossil fuel)

Please rank the sub-criteria of cultural, social, and behavioral barriers in order of importance (Table C.1.4).

Table C.1.4. The rank of the importance of cultural, social, and behavioral sub-criteria barriers

Criteria	**Rank**
Lack of social acceptance	( )
Low public awareness	( )

According to the identified sub-criteria of cultural, social, and behavioral barriers, and using 1 to 9 scales (in which nine indicates the extremely important, and one shows the equal important), please select the relative importance of option "A" (in the left column) to the option "B" (in the right column).

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
Lack of social acceptance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Low public awareness

Please rank the sub-criteria of political and regulatory barriers in order of importance (Table C.5).

Table C.1.5. The rank of the importance of political and regulatory sub-criteria barriers

Criteria	**Rank**
International sanctions	( )
The absence of proper international cooperation with the International REs Agency and World Bank	( )
The absence of sustainable energy and environmental policies	( )

According to the identified sub-criteria of political and regulatory barriers, and using 1 to 9 scales (in which nine indicates the extremely important, and one shows the equal important), please select the relative importance of option "A" (in the left column) to the option "B" (in the right column).

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
International sanctions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	The absence of proper international cooperation with the International REs Agency and World Bank
International sanctions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	The absence of sustainable energy and environmental policies
The absence of proper international cooperation with the International REs Agency and World Bank	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	The absence of sustainable energy and environmental policies

Please rank the sub-criteria of technical barriers in order of importance (Table C.1.6).

Table C.1.6. The rank of the importance of technical sub-criteria barriers

Criteria	**Rank**
Lack of infrastructure facilities	( )
Lack of skilled personnel	( )
The absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc.	( )

According to the identified sub-criteria of technical barriers, and using 1 to 9 scales (in which nine indicates the extremely important, and one shows the equal important), please select the relative importance of option "A" (in the left column) to the option "B" (in the right column).

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Lack of infrastructure facilities	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of skilled personnel
Lack of infrastructure facilities	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	The absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc.
Lack of skilled personnel	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	The absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc.

Please rank the sub-criteria of technical barriers in order of importance (Table C.7).

Table C.1.7. The rank of the importance of institutional sub-criteria barriers

Criteria	Rank
The absence of active banks and insurance companies in renewable energies	( )
The absence of an appropriate structure for encouraging and support of REs use and development	( )

According to the identified sub-criteria of institutional barriers, and using 1 to 9 scales (in which nine indicates the extremely important, and one shows the equal important), please select the relative importance of option "A" (in the left column) to the option "B" (in the right column).

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
The absence of active banks and insurance companies in renewable energies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	The absence of an appropriate structure for encouraging and support of REs use and development

C.1.2. Ranking more disadvantageous barriers to the development of the cost-effective REs in Iran

As declared by (Mostafaeipour & Mostafaeipour, 2009), solar and wind energy are more usable and convenient REs in the MENA countries and in Iran. Located on the Sun Belt (Fadai et al., 2011) and covered by numerous desert (Khojasteh et al., 2018), Iran has lots of proper areas to deploy solar energy. Indeed, it enjoys 2800 sunny hours yearly, the sunny hours in spring, summer, autumn, and winter are 700, 1050, 830, and 500 h, respectively. Besides owning enormous deserts, Iran is a mountainous land, with the Caspian Sea on its north, and the Persian Gulf, and the Oman sea on its southern part. These situations show the availability of high local wind energy potentials. Moreover, this country has several tropical winds flows, the Western flow from the Atlantic Ocean and the Mediterranean Sea, and the Central flow from the Indian Ocean during summer and the central flow from Central Asia during winters (Ghorashi & Rahimi, 2011). Moreover, Iran has a huge potential in biomass resource (Rezaee et al., 2019).

In this regard, to Rank more disadvantageous barriers to the development of the most cost-effective REs in Iran, please answer the following questions.

C.1.3. Guideline to fill the questionnaire up

Considering the numerical scales for pair-wise comparison, which has been shown in part 1, the relative weight of the chosen criteria amongst the two options was presented in Table C.1.3.1.

Table C.1.3.1. Empirical example to do pair-wise comparison

In terms of absence of private and state section's investment barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

The absence of a private and state section's investment is much more disadvantageous for biomass compared to the wind turbine.

The disadvantage of the absence of private and state section's investment is equal for biomass and solar PV.

The absence of private and state section's investment is extremely more disadvantageous for the wind turbine compared to solar PV.

1. In terms of the absence of private and state section's investment barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

2. In terms of lack of access to credit and long payback period barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

3. In terms of high initial investment and high costs of renewable technologies (providing subsidy for fossil fuel) barrier, which alternative do you think is more disadvantageous?

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

4. In terms of lack of social acceptance barrier, which alternative do you think is more disadvantageous?

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

5. In terms of low public awareness barrier, which alternative do you think is more disadvantageous?

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

6. In terms of international sanctions barrier, which alternative do you think is more disadvantageous?

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

7. In terms of the absence of proper international cooperation with the International REA and World Bank barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

8. In terms of the absence of sustainable energy and environmental policies barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

9. In terms of lack of infrastructure facilities barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

10. In Terms of lack of skilled personnel barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

11. In terms of the absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc. barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

12. In terms of the absence of active banks and insurance companies in REs barrier, which alternative do you think is more disadvantageous?

Option A	Extremely		Very strongly		strongly		Moderately		equally		Moderately		strongly		Very strongly		Extremely	Option B
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

13. In terms of the absence of an appropriate structure for encouraging and support of REs use and development barrier, which alternative do you think is more disadvantageous?

Option A	**Extremely**		**Very strongly**		**strongly**		**Moderately**		**equally**		**Moderately**		**strongly**		**Very strongly**		**Extremely**	**Option B**
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power
Solar PV	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Biomass
Biomass	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wind power

C.1.4. Demographic and general information of the respondent

Age: ………………………………………………………………year

Gender: ……………………………………….………………….

Workplace: ………………………………………………...………..

Job position: ……………………………………………………........

Work experience: ………………………………………………year

Email address: ……………………………………………………….

Contact number: …………………………………………………….

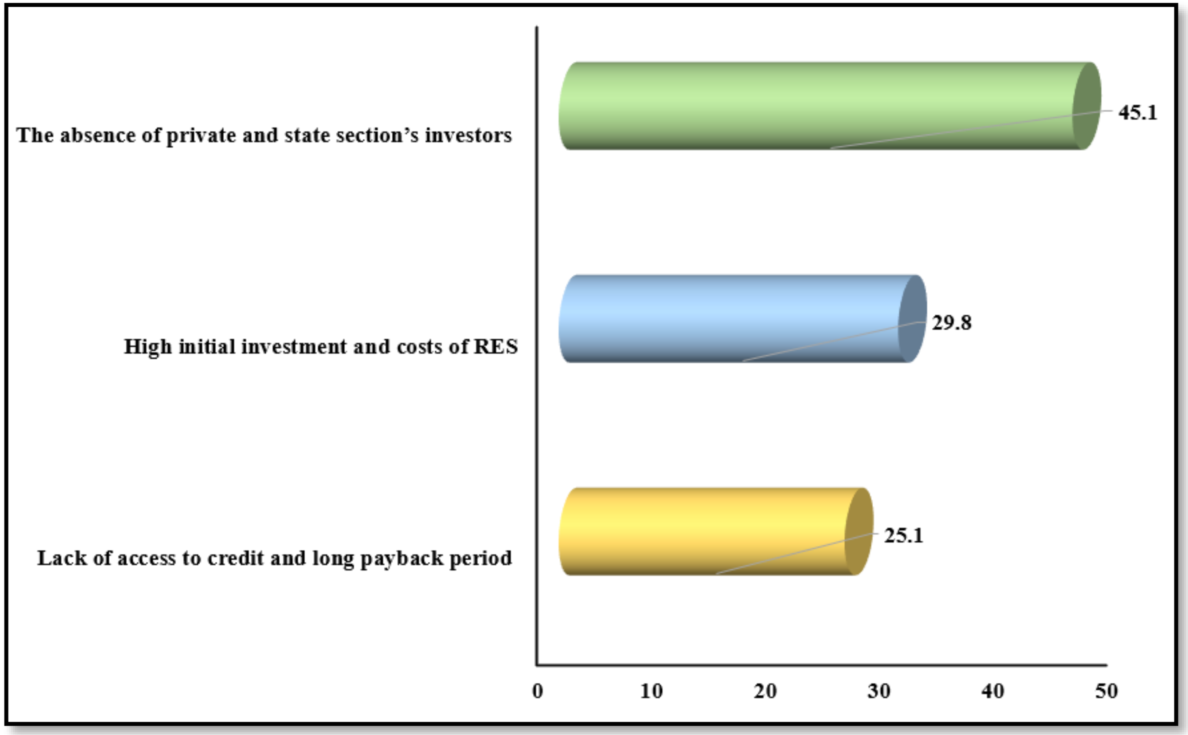
The information provided by respondents would be kept confidential and will not be disclosed. Indeed, the responses would be used only for academic purposes.

To improve the quality of this survey, please share your concerns, comments, recommendations, and questions with us through following email address:

bahare.oryani@snu.ac.kr, bahare.oryani@gmail.com.

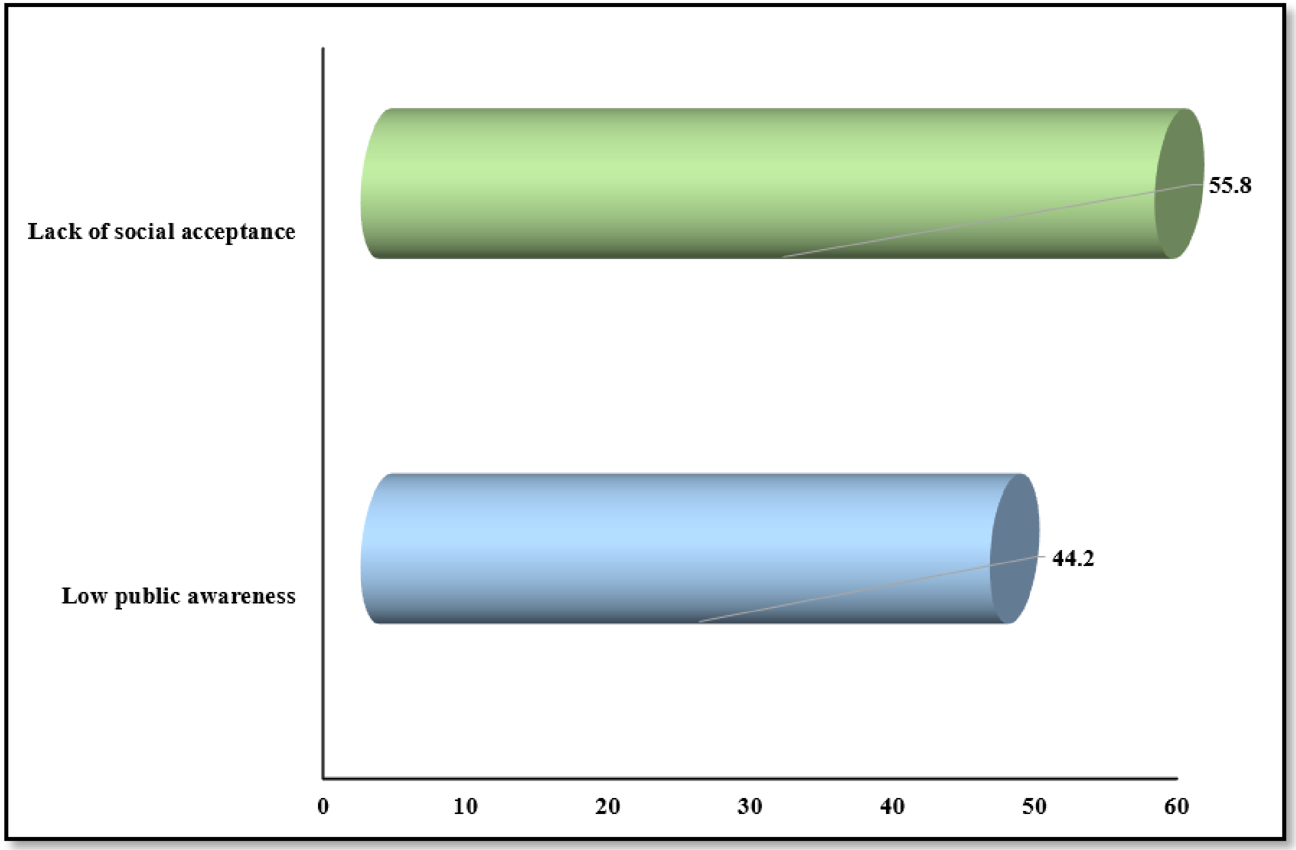
Thanks again for your time and participation

C.2. Ranking of sub-criteria in each criterion



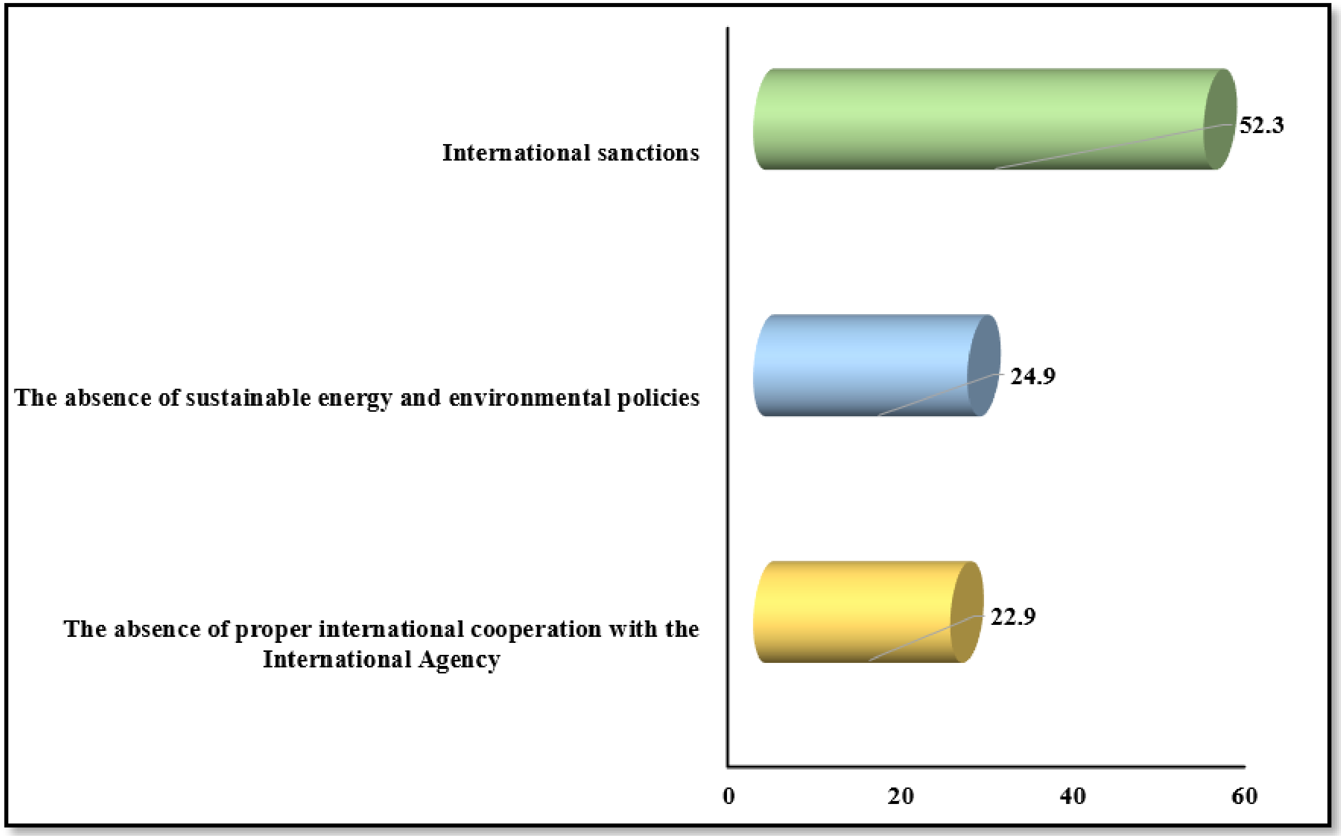
Consistency Ratio (CR): 0.00151

Figure C.2.1. Synthesis of the economic and financial barriers



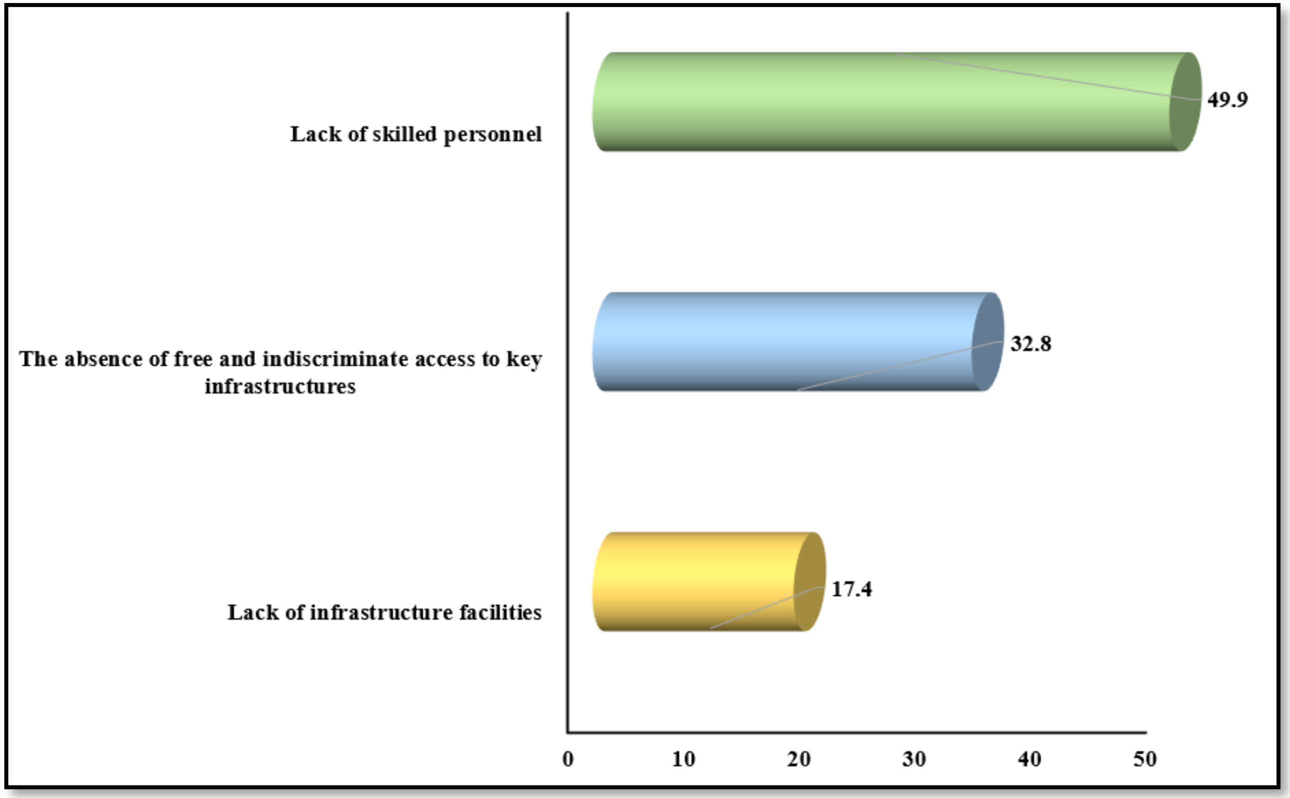
Consistency Ratio (CR): 0.000

Figure C.2.2. Synthesis of the social, cultural, and behavioral barriers



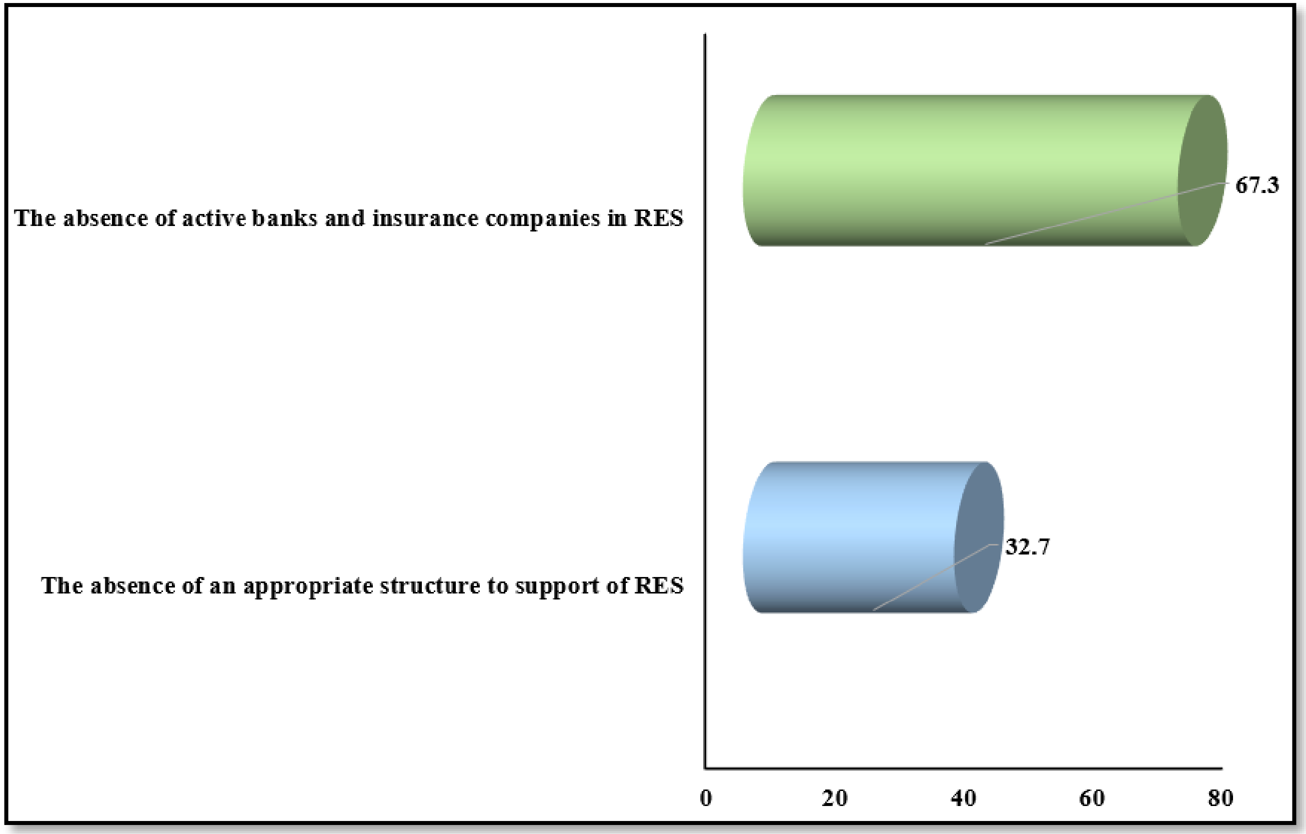
Consistency Ratio (CR): 0.00961

Figure C.2.3. Synthesis of the political and regulatory barriers



Consistency Ratio (CR): 0.00001

Figure C.2.4. Synthesis of the technical barriers

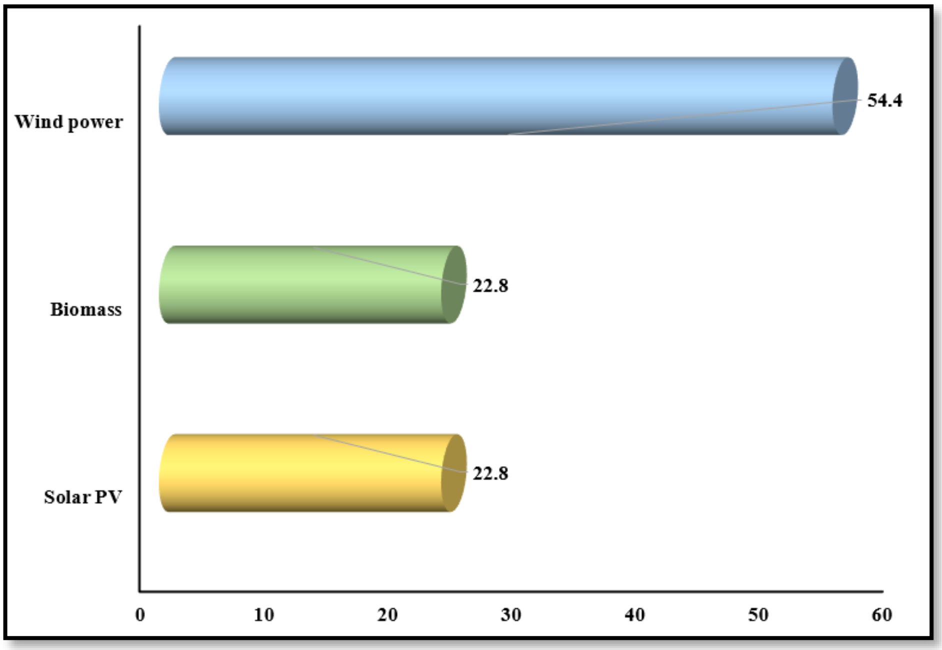


Consistency Ratio (CR): 0.0000

Figure C.2.5. Synthesis of the institutional barriers

C.3. The relative importance of alternatives based on the barriers

The relative importance of studied alternatives based on each sub-criterion was reported in the following section.

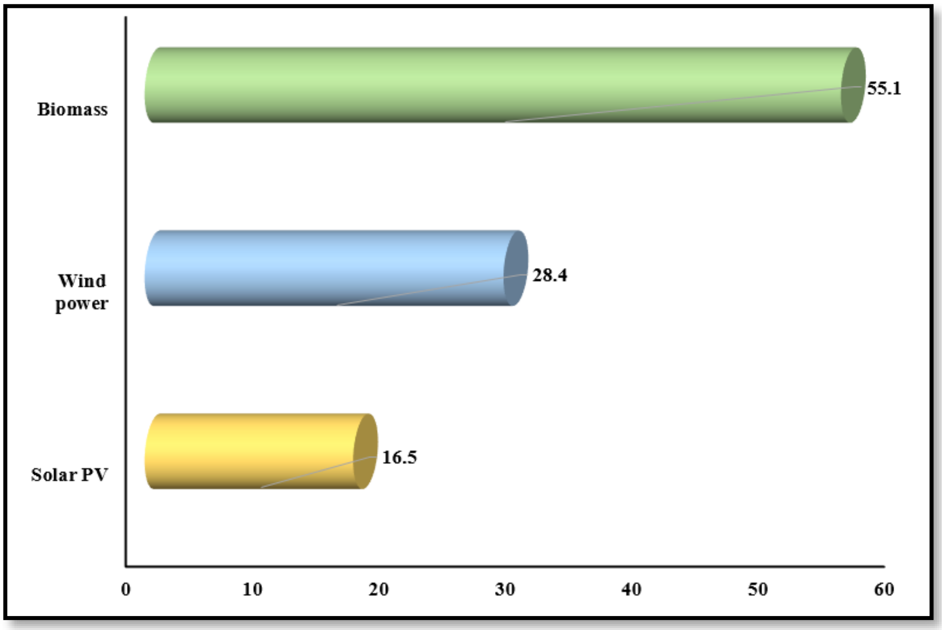


Consistency Ratio (CR): 0.02

Figure C.3.1. The relative importance of alternatives with respect to the absence of private and state section's investors

As illustrated in Figure C.3.1, the absence of private and state section's investment was the most challenging impediments to the development of wind power (54.4%) followed by solar PV (22.8%), and biomass (22.8%).

The relative importance of the investigated alternatives based on the lack of access to credit and long payback period was presented in Figure C.3.2.

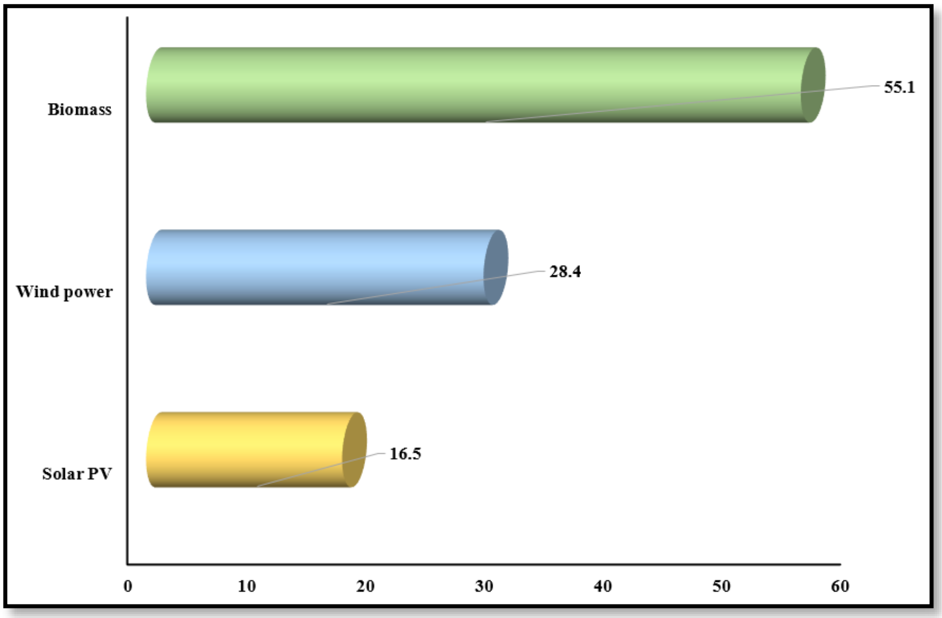


Consistency Ratio (CR): 0.00003

Figure C.3.2. The relative importance of alternatives with respect to the lack of access to credit and the long payback period

As shown in Figure C.3.2, lack of access to credit and the long payback period was the biggest impediments to the development of biomass (55.1%), wind power (28.4%), and solar PV (16.5%), respectively.

The relative importance of the intended alternatives based on high initial investment, and high costs of renewable technologies (providing subsidy for fossil fuel) was shown in Figure C.3.3.

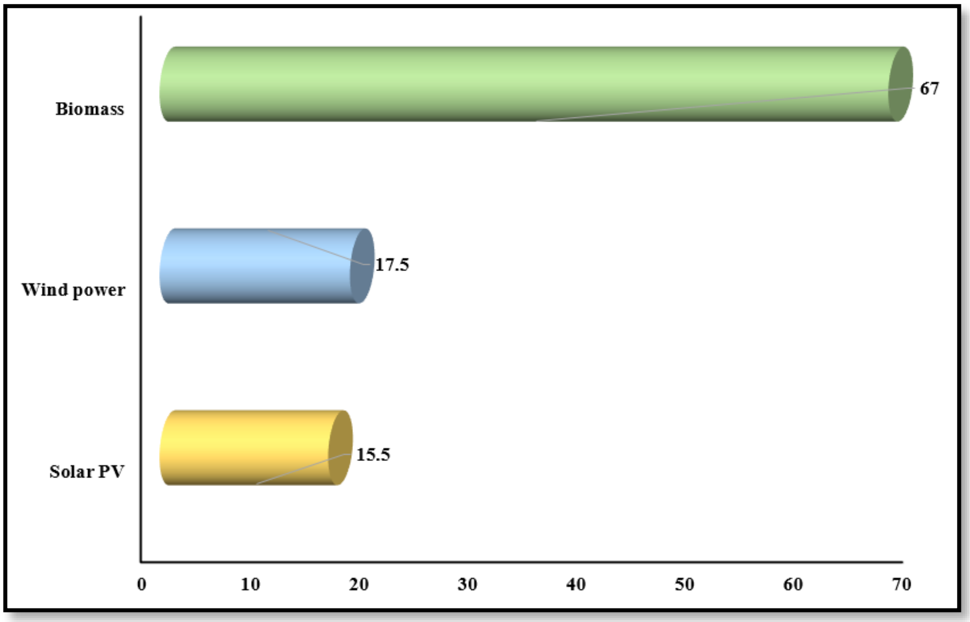


Consistency Ratio (CR): 0.00151

Figure C.3.3. The relative importance of alternatives with respect to high initial investment and costs of REs

From Figure C.3.3, high initial investment, and costs of REs was the biggest restrictions to the development of the biomass (55.1%), followed by a wind power (28.4%), and solar PV (16.5%).

The relative importance of investigated alternatives based on the lack of social acceptance was shown in Figure C.3.4.

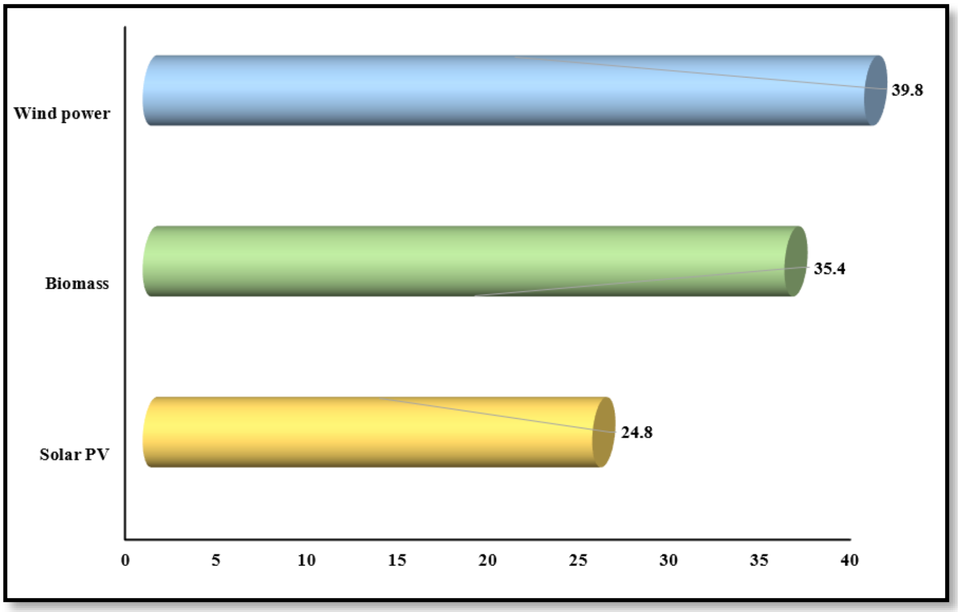


Consistency Ratio (CR): 0.0005

Figure C.3.4. The relative importance of alternatives with respect to the lack of social acceptance

As can be seen in Figure 7, the lack of social acceptance had the highest hindrance effect on the development of the biomass (67%), followed by a wind power (17.5%), and solar PV (15.5%).

The relative importance of the studied alternatives based on low public awareness was presented in Figure C.3.5.

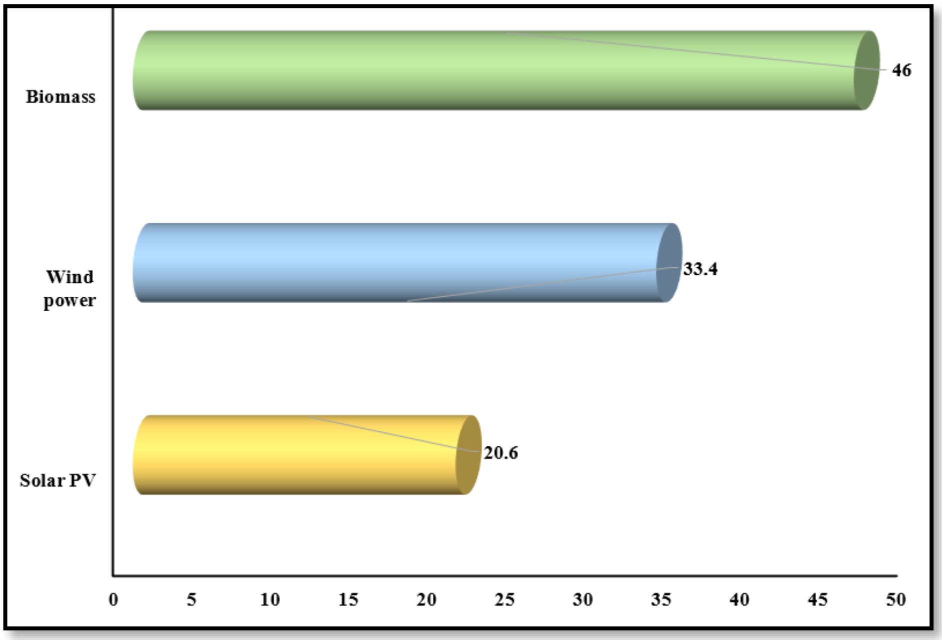


Consistency Ratio (CR): 0.00376

Figure C.3.5. The relative importance of alternatives with respect to low public awareness

As pictured in Figure 8, low public awareness had the most significant deterrent effect on the expansion of wind power (39.8%), followed by biomass (35.4%), and solar PV (24.8).

The relative importance of the intended alternatives based on the international sanctions was shown in Figure C.3.6.

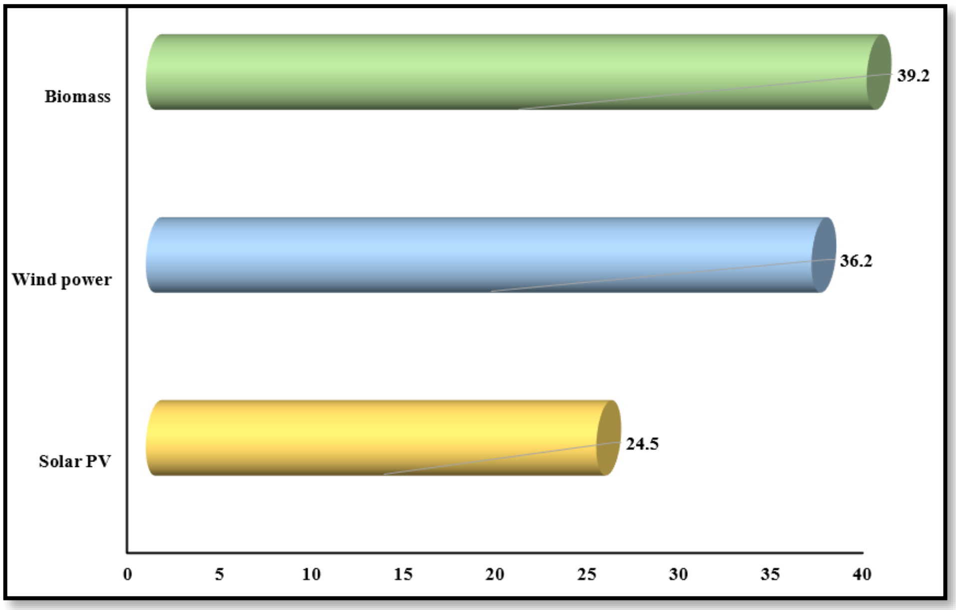


Consistency Ratio (CR): 0.00003

Figure C.3.6. The relative importance of alternatives with respect to international sanctions

As exhibited in Figure C.3.6, the imposing international sanction against Iran had the highest deterrent effect on the expansion of biomass (46%), followed by a wind power (33.4%), and solar PV (20.6%).

The relative importance of the studied alternatives based on the absence of proper international cooperation with IREA and World Bank was presented in Figure C.3.7.

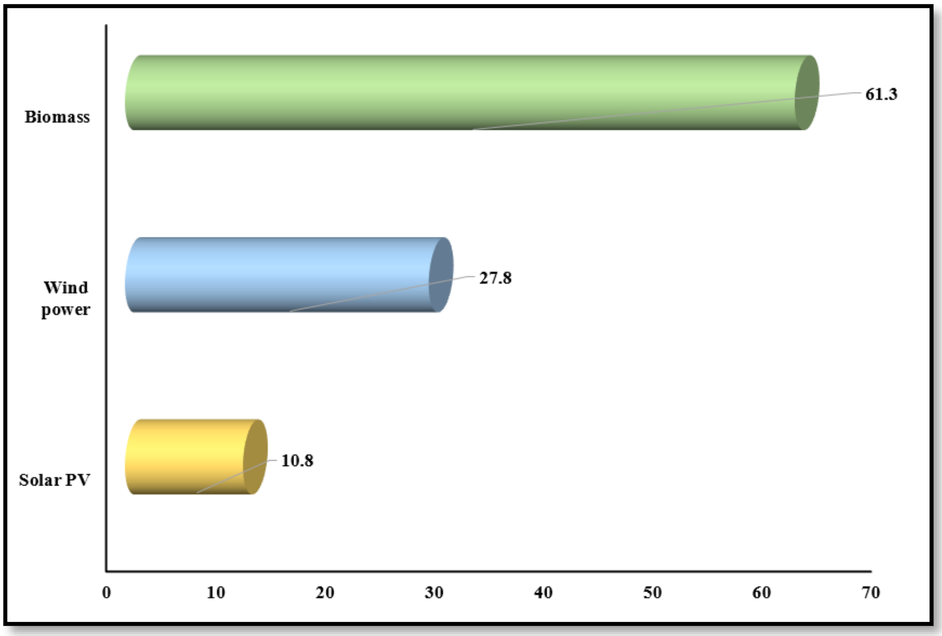


Consistency Ratio (CR): 0.00036

Figure C.3.7. The relative importance of alternatives with respect to the absence of proper international cooperation with the International Agency

From Figure C.3.7, absence of proper international cooperation with the International REA and World Bank was the most powerful barriers to the development of biomass (39.2%), followed by a wind power (36.2%), and solar PV (24.5%).

The relative importance of the studied alternatives based on the absence of sustainable energy and environmental policies was depicted in Figure C.3.8.

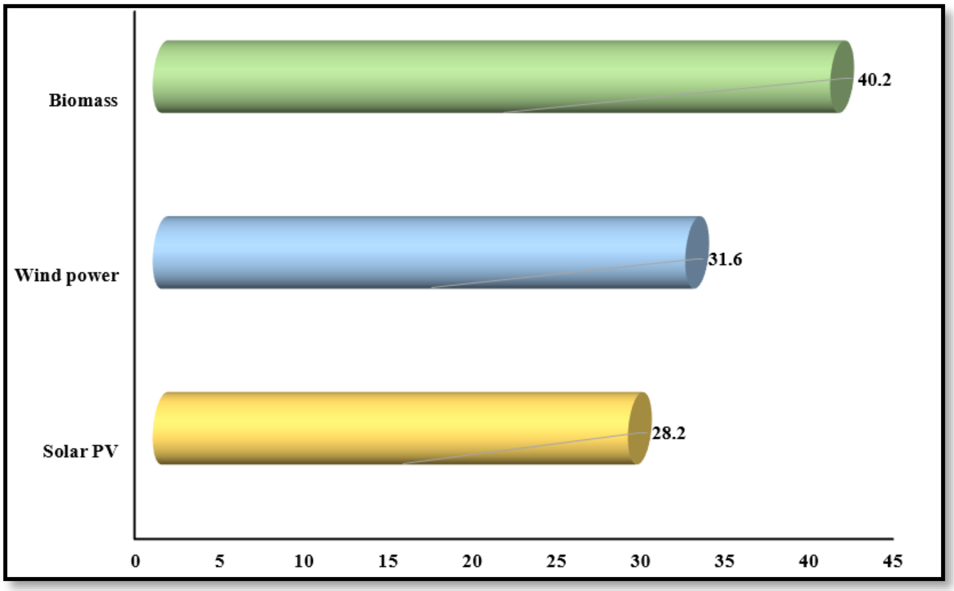


Consistency Ratio (CR): 0.01

Figure C.3.8. The relative importance of alternatives with respect to the absence of sustainable energy and environmental policies

As represented in Figure C.3.8, The absence of sustainable energy and environmental policies had the largest restraint effect on the development of biomass (61.3%), followed by a wind power (27.8%), and solar PV (10.8%).

The relative importance of the investigated alternatives based on Lack of infrastructure facilities was shown in Figure C.3.9

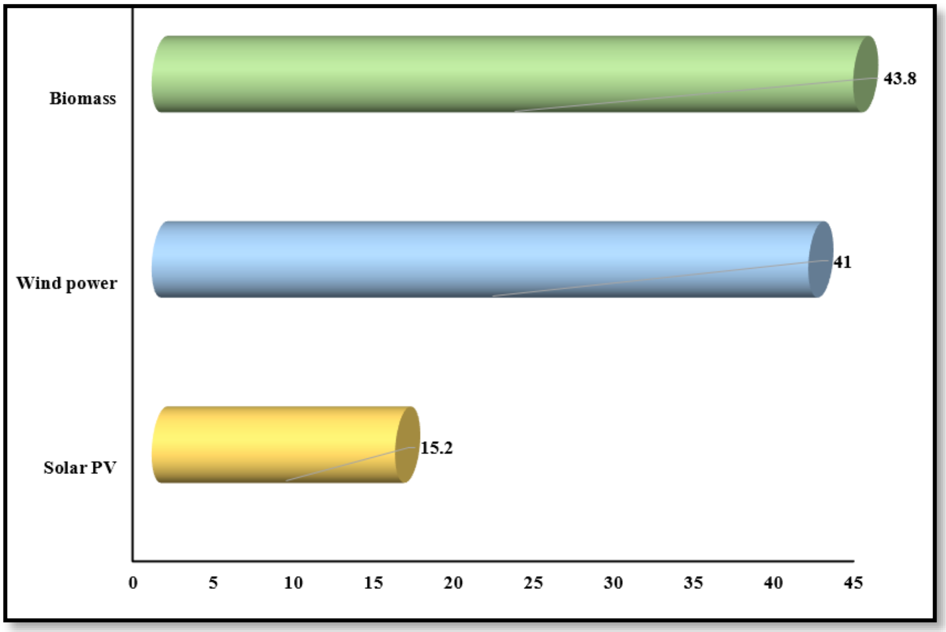


Consistency Ratio (CR): 0.0051

Figure C.3.9. The relative importance of alternatives with respect to the lack of infrastructure facilities

As can be viewed in Figure C.3.9, lack of infrastructure facilities had the highest adverse impacts on the development of biomass (40.2%), followed by a wind power (31.6%), and solar PV (28.2%).

The relative importance of the reviewed alternatives based on the lack of skilled personnel was depicted in Figure C.3.10.

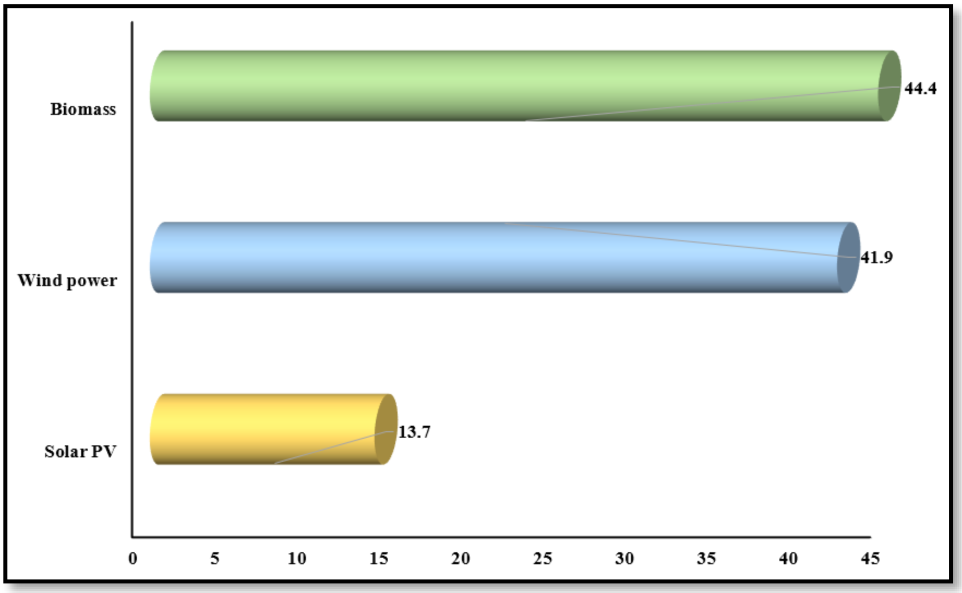


Consistency Ratio (CR): 0.00177

Figure C.3.10. The relative importance of alternatives with respect to the lack of skilled personnel

From Figure C.3.10, the lack of skilled personnel was identified as the main hindrance to the development of biomass (43.8%), followed by a wind power (41%), and solar PV (15.2%).

The relative importance of the studied alternatives based on the absence of free and indiscriminate access to key infrastructures of energies such as national electricity network etc. was illustrated in Figure C.3.11.

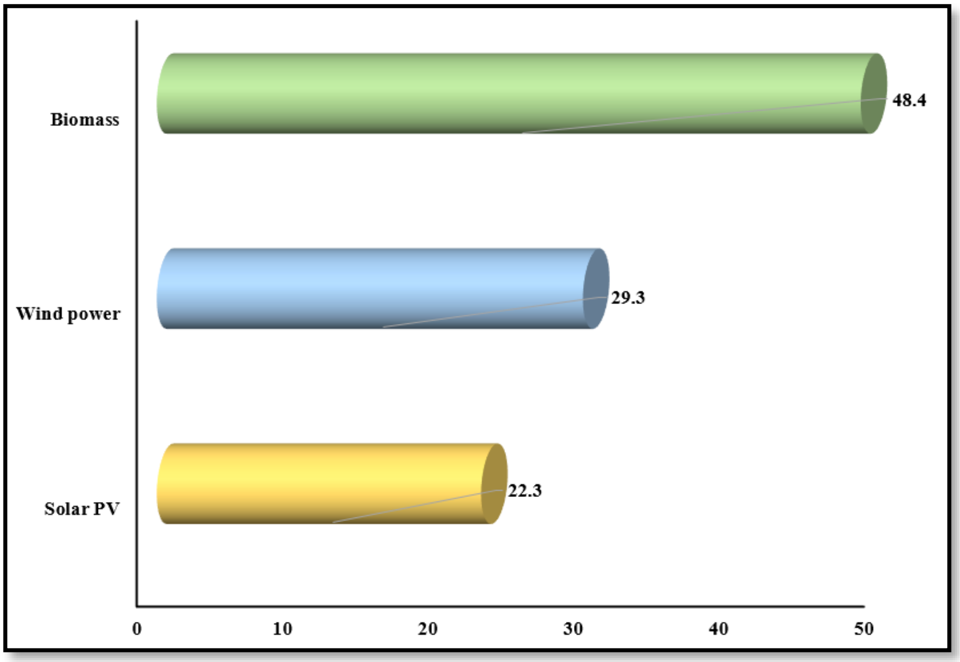


Consistency Ratio (CR): 0.01

Figure C.3.11. The relative importance of alternatives with respect to the absence of free and indiscriminate access to key infrastructures

As represented in Figure C.3.11, the absence of free and indiscriminate access to key infrastructures of energies such as national electricity network, etc. had the highest adverse impacts on the extension of biomass (44.4%), followed by a wind power (41.9%), and solar PV (13.7%).

The relative importance of the intended alternatives based on the absence of active banks and insurance companies in REs was shown in Figure C.3.12.

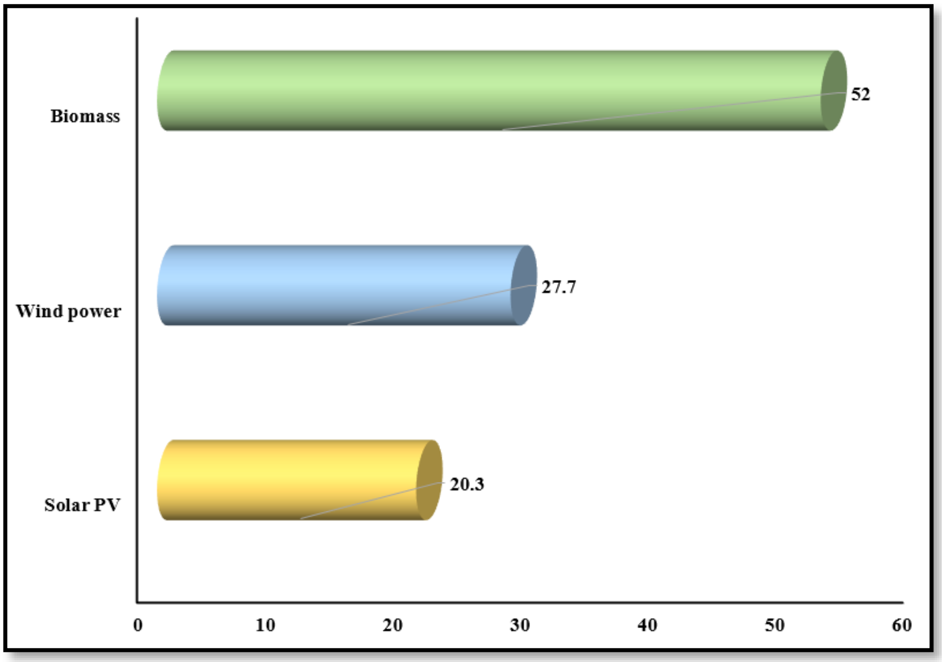


Consistency Ratio (CR): 0.00648

Figure C.3.12. The relative importance of alternatives with respect to the absence of active banks and insurance companies in REs

As can be noticed in Figure C.3.12, the absence of active banks and insurance companies in REs had the highest hindering consequences on the development of biomass (48.4%), followed by a wind power (29.3%), and solar PV (22.3%).

The relative importance of the reviewed alternatives based on the absence of an appropriate structure for encouraging and support of REs use, and development was drawn in Figure C.3.13.



Consistency Ratio (CR): 0.00432

Figure C.3.13. The relative importance of alternatives with respect to the absence of an appropriate structure to support of REs

From Figure C.313, the absence of an appropriate structure for encouraging and support of REs use, and development was determined as the most influential barriers to the development of biomass (52%), followed by a wind power (27.7%), and solar PV (20.3%).

C.4. Global ranking of barriers regarding each alternative

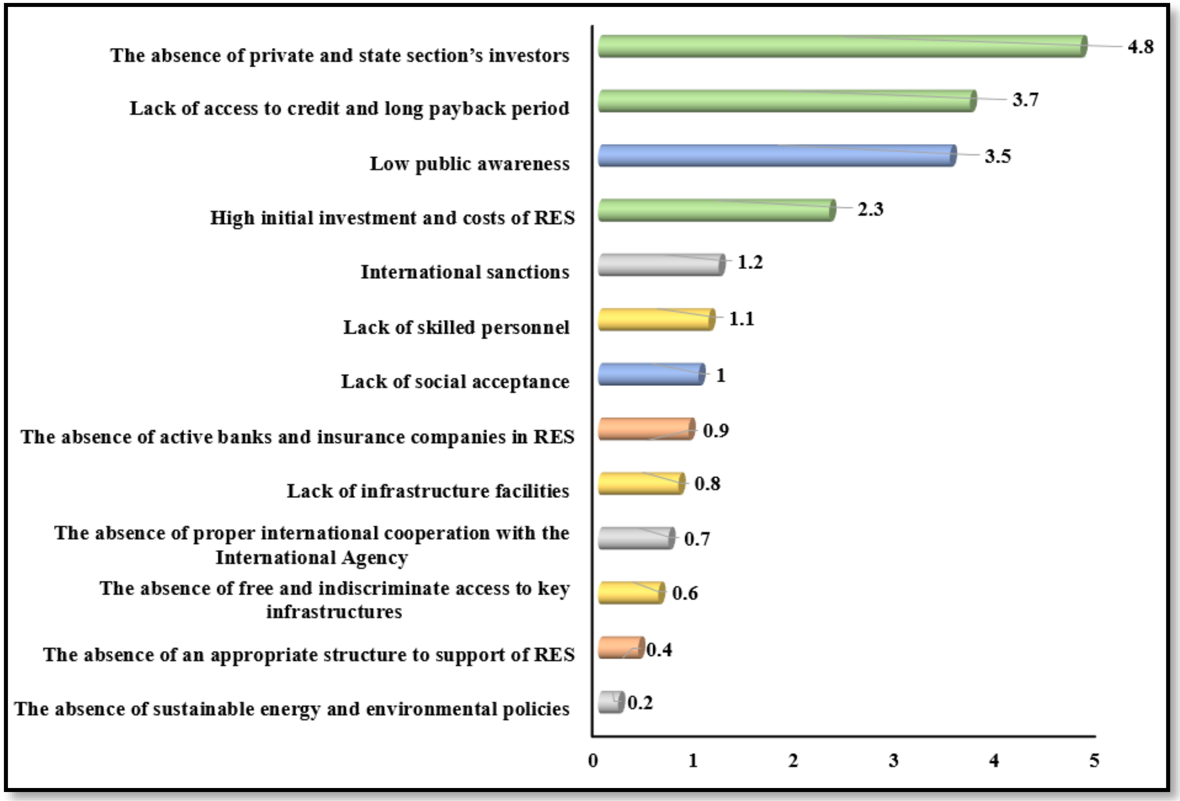


Figure C.4.1. Overall ranking of barriers to solar PV

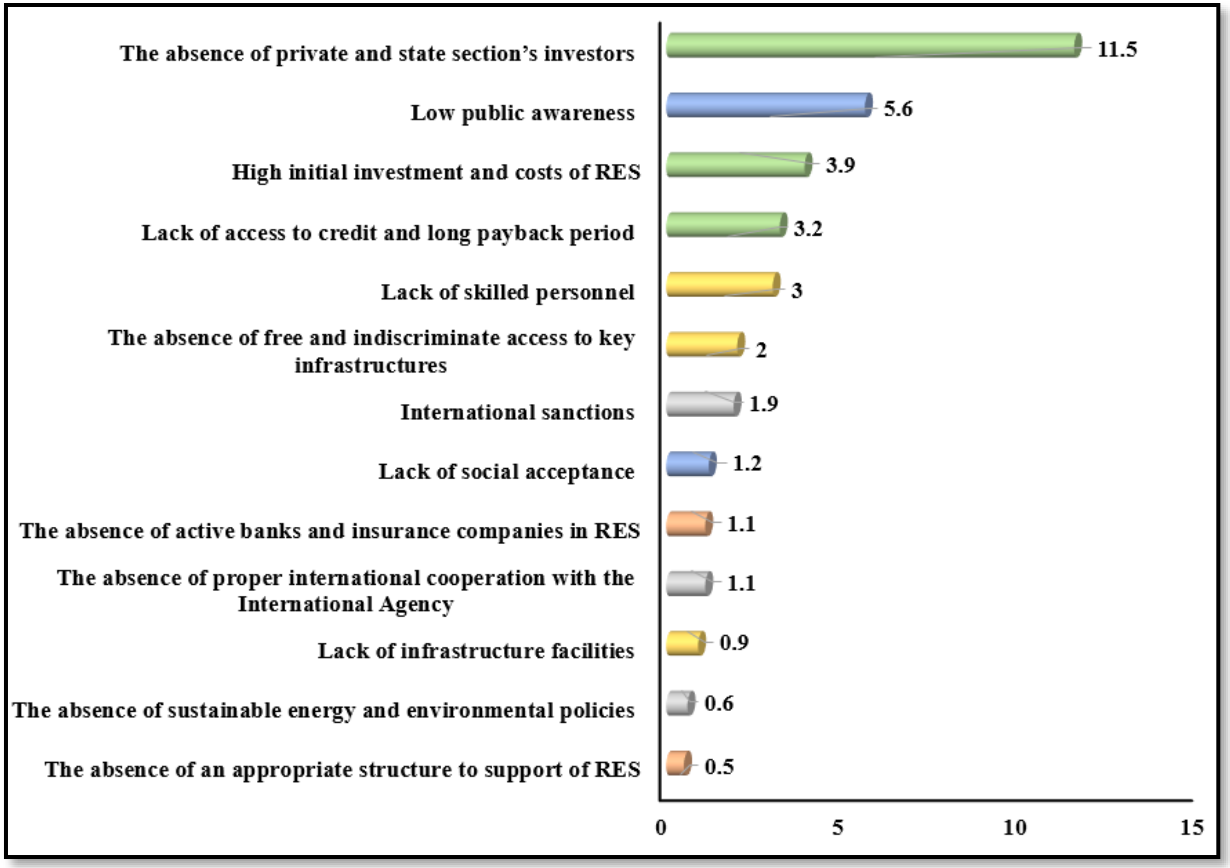


Figure C.4.2. Overall ranking of barriers to wind power

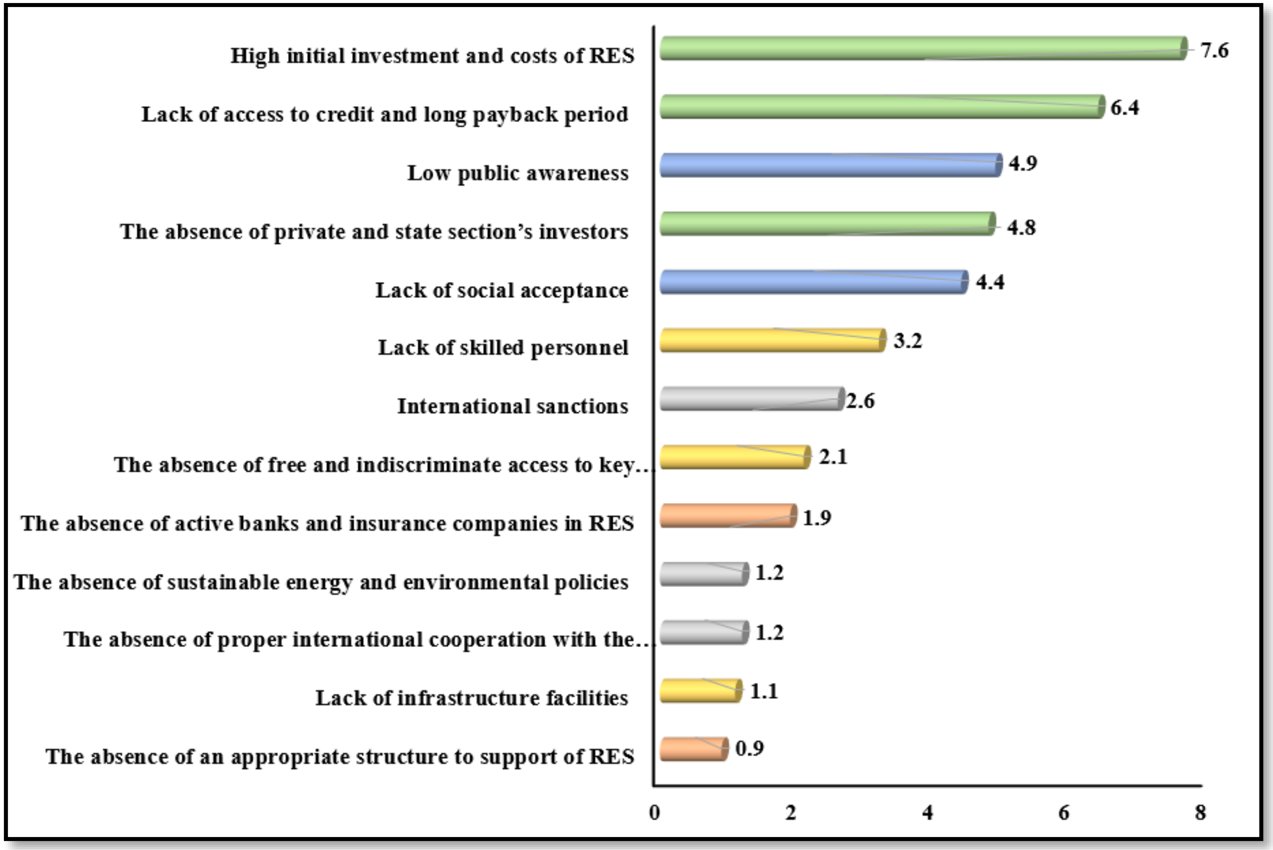


Figure C.4.3. Overall ranking of barriers to biomass

Abbreviation

3SLS: Three-Stage Least Squares

ADB: Asian Development Bank

ADF: Augmented Dicky Fuller

ADM: Administrative

AEC: Alternative Energy consumption

AFVs: Alternative Fuel Vehicles

AGL: Agricultural Land

AGR: Agriculture Value Added

AHP: Analytical Hierarchy Analysis

AI: Awareness and Information

AIC: Akaike information criterion

ARDL: Autoregressive Distributed Lag

ASC: Alternative-Specific Constant

BE: Biomass Energy Consumption Per Capita

BEVs: Battery Electric Vehicles

BRICs: Brazil, Russia, India, China, and South Africa

BRT: Bus Rapid Transit

C.R.: Consistency Ratio ()

CBIIR: Central bank of Islamic Republic of Iran

CC: Competition Council

CE: Choice Experiment

COC: Chamber of Commerce

CRE: Per Capita Combustible Renewable Energy Waste

CUSUM: Cumulative Sum ff Recursive Residuals

CUSUMQ: Cumulative Sum ff Recursive Residuals of Square

CV: Contingent Valuation

DCE: Discrete Choice Experiment

DIN: Domestic Investment

DOEIRI: The Department of Environment Islamic Republic of Iran

DOI: Diffusion of Innovation

DPF: Diesel Particulate Filter

E: Experience

EA: Environmental Attitude

EC: Energy Consumption

ECM: Error-Correction Model

EF: Economic & Financial

EFA: Explanatory Factor Analysis

EG: Ecological and Geographical

ELF: Electricity Consumption from Fossil Fuel Sources

ELN: Electricity Generation from Non-Renewable Sources

ELR: Electricity Consumption from Renewable Sources

ENE: Energy Use

ENV: Environmental

EP: Energy Production from Oil Sources (as a percentage of total)

EPR: Per Capita Renewable Electricity Production

EVs: Electric Vehicles

EX: Export

FCEVs: Fuel Cell Eclectic Vehicles

FD: Financial Development

FDI: Foreign Direct Investment

FERF: Foreign Exchange Reserve Funds

GAS: Dry Natural Gas Consumption Per Capita

GCF: Per Capita Gross Capital Formation

GH: Gregory-Hansen Co-Integration

HCM: Hybrid Choice Model

HCOTVSE: Higher Council of Technical, Vocational and Skills Education

HDI: Human Development Indicator

HDVs: High-Duty Vehicles

HEVs: Hybrid Electric Vehicles

HJ: Hatemi-J Co-Integration

HS: Human Skills

HYP: Hydropower Consumption

ICEs: Internal Combustion Engines

ICEVs: Internal Combustion Engine Vehicles

IDRO: Industrial Development and Renovation Organization of Iran.

IIAs: Independence from Irrelevant Alternatives

IIECo: Iran International exhibitions Co

IKCO: Iran Khodro Company

IM: Import

IMF: International Monetary Funds

INF: Inflation

INS: Institutional

INTA: Iranian National Tax Administration

IREA: International Renewable energy Agency

IRIB: Islamic Republic of Iran Broadcasting

ISV: Individual-Specific Variables

K: Capital

KMO: Kaiser-Meyer-Olkin

L: Labor Force

LA: Land

LACC: Latin America and the Caribbean Countries

LCM: Latent Class Model

LOEIR: Commission of Article 1 of the Law on Export and Import Regulations

M: market-related dimension

MADM: Multi-Attribute Decision-Making Method

MENA: Middle East and North Africa

MF: Monetary Factors

MG: Mean Group

MIMT: The Ministry of Industry, Mine, and Trade of Iran

MLX: Mixed Logit Model

MNL: Multinomial Logit

MOE: The Ministry of Energy

MOEAF: The Ministry of Economic Affairs and Finance

MOED: The Ministry of Education

MOFA: The Ministry of Foreign Affairs

MOIMT: The Ministry of Industry, Mine and Trade

MOP: The Ministry of Petroleum

MWTP: Marginal Willingness To Pay

NL: Nested Logit

NRE: Per Capita Non-Renewable Energy/ Fossil Fuels Consumption

NUC: The Portion of Nuclear Electricity of the Total Electricity Generation

NV: Number of Vehicles (Imported and Produced) on the Road

OECD: The Organization for Economic Co-Operation and Development

OPEC: The Organization of The Petroleum Exporting Countries

PBC: Perceived Behavioral Control

PBO: Plan and Budget Organization

PC: Energy Price

PD: Population Density

PDWG: Production Development Working Group

PHEVs: Plug-in Hybrid Electric Vehicle

PMGE: Pooled Mean Group Estimator

PNG: Per Capita Natural Gas Consumption

POIL: Total Petroleum Consumption Per Capita

POP: Population Growth

PP: Philips Perron

PPEC: Per Capita Primary Energy Consumption

PR: Policy (Political) and Regulatory

QI: Quality of Institutions

R.Ix.: Random Index

REEVs: Range Extended Electric Vehicles

REP: Renewable Energy Portion in Total Energy Generation

REs: Renewable Energies

RET: Renewable Energy Technology

RI: Relative Importance

RP: Revealed Preference data

RPEX: Real Per Capita Export

RPIM: Real Per Capita Import

RPL: Random Parameter Logit

SCB: Social, Cultural, and Behavioral

SHARE: The Industrial GDP to Total GDP Ratio

SI: Social Influence

SIC: Schwarz information criterion

SNSC: Supreme National Security Council

SP: Stated Preference

SPDCE: Stated Preference Discrete Choice Experiment

T: The Ratio of Merchandise Export to Merchandise Import

TCC: Total Consumer Cost

TECH: Technical

TECHN: Technological

TFP: Total Factor Productivity

TI: International Trade

TO: Trade Openness

TP: Technical Performance

TPO: Trade promotion organization of Iran

TR: Foreign Trade

TS: Traditional Segmentation

ULCM: Unconditional Linear Correction Model

URB: Urbanization.

VECM: Vector Error Correction Model

VPST: The Vice Presidency for Science and Technology

WTP: Willingness to Pay

Y: Per Capita Real GDP

Y^2: Per Capita Real GDP (Squared)

요약 (Abstract)

이 연구는 이란의 온실가스 배출량에 큰 비중을 차지하는 전력 및 수송 부문에 대한 녹색 성장 전략을 제안하는 것을 목적으로 하고 있다. 이를 위해 다음 세 개의 에세이를 수행하였다.

첫 번째 에세이에서는 ARDL(Autoregressive Distributed Lag) 및 ECM(Error-Correction Model)을 이용하여 에너지 믹스 및 수송 부문이 온실가스 배출량에 미치는 영향을 분석하였다. 그 결과, 온실가스 배출량 감축에 장단기적으로 재생에너지는 긍정적인 영향, 경제 성장은 부정적인 영향을 미치는 것으로 나타났다. ECM-Granger 인과성 검정 결과 장기적으로 경제 성장과 차량 수가 온실가스 배출을 유발하는 것으로 확인되었다. 자동차의 수는 경제 성장과 CO_2 배출에 모두 긍정적인 영향을 미치기 때문에, 내연 기관 차량(ICEV)을 대체 연료 차량(AFV)으로 대체함으로써 경제 성장을 촉진함과 동시에 도로 교통 배출로 인한 환경 부작용을 줄일 수 있음을 보였다. 그러나 이는 AFV 충전에 필요한 전기가 재생에너지를 통해 발전될 경우에 가능한다.

두 번째 에세이는 이란의 4 대 도시에서 전기 자동차 (EV)에 대한 지불 의사를 분석하였다. 혼합로짓모델(MLX)의 결과는 구매 가격 (46.40 %), 연료 유형 (24.05 %), 충전소 가용성 (12.88 %), 비 금전적 인센티브 정책 순서로 구매에 영향을 미치는 것으로 나타났다. 또한 잠재 소비자는 낮은 구매 가격과 연료비를 선호했다. 시장 시뮬레이션 결과는 단일 정책보다는 종합적인 정책의 효과가 더 큰 것으로 나타났고, 이는 소비자의 이질성(각 속성에 대한 선호도 및 중요도가 소비자마다 다름)에 의한 것으로 보인다. LCM(Latent Class Model) 은 소비자 선호 유형에 따라 세 가지 소비자 그룹을 보여 주었으며, 이는 시장에서 EV의 보급률을 높이기 위한 수송 정책을 설계 할 때 고려해야 할 사항이다.

세 번째 에세이의 목표는 다음과 같이 두 가지이다. 첫째, 이란의 재생에너지(RE) 개발에 대한 걸림돌을 식별하여 순위를 매기고, 둘째, 태양광, 풍력 및 바이오 매스 중에서 가장 비용 효율적인 RE를 찾는 것이다. 문헌 조사 및 전문가 설문을 통해 13 개의 재생에너지 보급에 걸림돌이 되는 요인을 식별하여 경제 및 금융, 사회, 문화 및 행동, 정치 및 규제, 기술 및 제도의 5 개 그룹으로 분류하였다. 확인 된 걸림돌에 대한 전문가의 의견을 얻기 위해 AHP(Analytical Hierarchy Analysis)를 이용한 비교 조사를 수행했다. 그 결과, 경제적, 재정적, 사회적, 문화적, 행동 적, 기술적, 정치적, 규제 적, 제도적 장벽 순서로 RE 보급에 부정적인 영향을 미치는 것을 알 수 있었다. 이러한 장애 요인을 종합적으로 분석해 봤을 때 태양광 발전, 풍력 발전, 바이오 매스 발전 순서로 장애 요인이 더 적은 것을 식별하였다. 따라서 정부는 재생에너지 소비에 대한 최소 목표를 설정하는 형태로 지원 정책을 설계할 때 비용 효율적인 재생에너지 옵션으로 태양광 발전에 더 많은 관심을 기울여야 한다. 마지막으로 체계적 경쟁력 모형(systemic competitiveness model)을 기반으로 관련 전략 및 실행 계획을 Micro-level, Messo 수준, Macro 수준, Meta 수준의 4 단계로 제안하였다.

키워드: 녹색 성장 전략, 신 재생 에너지, 전기 자동차, 혼합 로짓, ARDL, 공동 통합 회귀, AHP

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