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Long-term electricity demand forecast by combining interpretive-structural modeling methods and system dynamics: The case of Iran

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Abstract

Electricity demand is continuously increasing in developed and developing countries. The accurate estimation of power consumption in the long-term horizon is of great importance for planning in the field of power generation and the management of the demand section. The use of a single model to forecast the consumption of all economic sectors leads to many errors, due to the different sectors consuming electricity in each country, as well as the difference in indicators and their changes in each sector. Hence, new research has highly considered the use of the decomposition approach of different consumer sectors. In this regard, identifying the fundamental factors of each sector and implementing the relationships between factors in an integrated platform for estimation are the two main issues in this area. The present study proposed a combination of interpretive-structural modeling and system dynamics (ISMSD). This method can evaluate scenarios and design policies to help decision makers. According to this methodology, Iran's electricity demand has been estimated as a developing country. The results of the evaluation highlighted the high accuracy of this method in prediction. Finally, the impact of energy subsidy targeting on Iran's electricity demand was investigated in three scenarios.

Keywords: Electricity demand forecast, system dynamics, interpretive-structural modeling (ISM), economical Sector

1- Introduction

Energy, as an influential element in the development of a country, plays a crucial role in the development and advancement of societies. Today, many societies and governments have considered energy management as one of the challenging issues. Meanwhile, electricity plays an influential important role in this way, as one of the most important energies of modern life in social welfare, as well as the productivity of work and production. The importance of electricity can be selected as appropriate energy, due to the possibility of using modern technologies and environmental considerations in all fields of activity. Regarding the importance of electricity demand, governments in developed and developing countries

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consider production management and electricity consumption as one of their most important tasks in the field of energy management. In order to realize this task, accurate estimation of power consumption is regarded as one of the definitive requirements for making the right decisions and providing appropriate solutions (Bhattacharyya and Timilsina, 2009).

Electricity demand, as one of the main components of economic and social development, is constantly increasing (Nevzat and Haydar, 2010). Electrical energy is directly connected to the crucial elements of today's world and its consumption is growing for many reasons, including population growth, urbanization, and industrialization. During recent decades, the economic growth trend of the developed countries has indicated that the increase of national income and gross domestic product (GDP) has been associated with the growth of technological innovations and the increase of the electricity share in the energy basket, leading to a significant reduction in energy intensity. In addition, the per capita electricity consumption of developed countries is greatly higher than that of the developing countries (Ardakani and Ardehali, 2014).

The present study aimed to provide a method for long-term electricity demand forecast, which cannot be achieved with retrospective methods such as time-series because the factors affecting power consumption are undergoing fundamental changes. On the other hand, power consumption in different economic sectors may have a different trend and consequently, the estimation of power consumption causes errors in these areas, especially in examining the policies imposed on consumption. Figure 1 illustrates Iran’s electricity demand during 2008-2018 to further explain this issue. In general, electricity consumption has increased almost linearly by 60% from about 96 to 154 million barrels of crude oil. Thus, statistical methods may be reliable to predict power consumption. Further, in 2010, the targeted energy subsidy plan in Iran was adopted to be implemented, although no significant impact was observed on electricity consumption according to this chart.

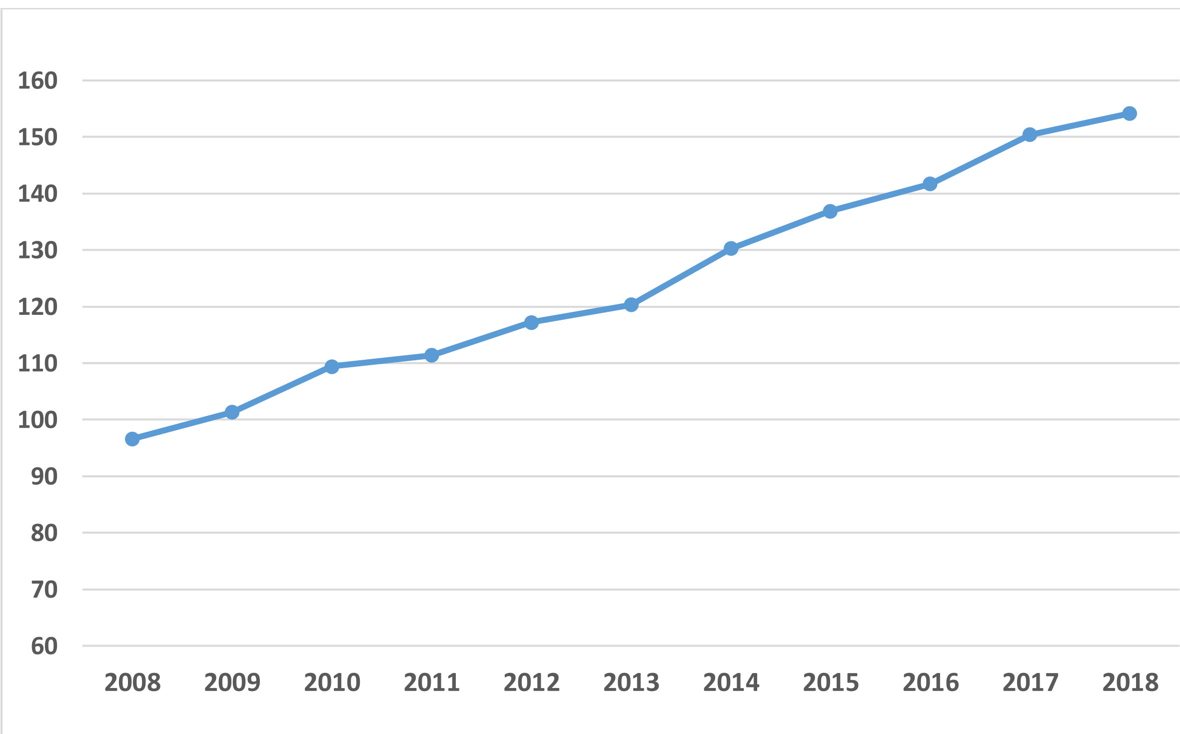

Fig. 1 Power consumption trend in Iran (in million barrels of crude oil)

Figure 2 depicts electricity demand in different sectors of the economy during 2008-2018. As observed, the power consumption trend in various sectors is somewhat different. In particular, with the implementation of the targeted energy subsidy law and the price reform of energy carriers in 2010, the commercial and residential sectors have faced with the decline in the consumption growth while the industrial and agricultural sectors have indicated an increase in the power consumption growth. It is necessary to consider the mechanisms and relationships between the effective factors of these sectors in order to predict power consumption. Therefore, identifying effective factors in each sector, determining the level of effectiveness, and specifying the relationships between the factors of that sector are the main problem in predicting power consumption. As mentioned above, the targeted energy subsidy has imposed effects on the power consumption of each sector, due to different existing factors or relationships, which should be considered in the prediction. For these reasons, an appropriate tool should be first selected and then, some measures should be taken to predict the power consumption, which these two steps are addressed in the following.

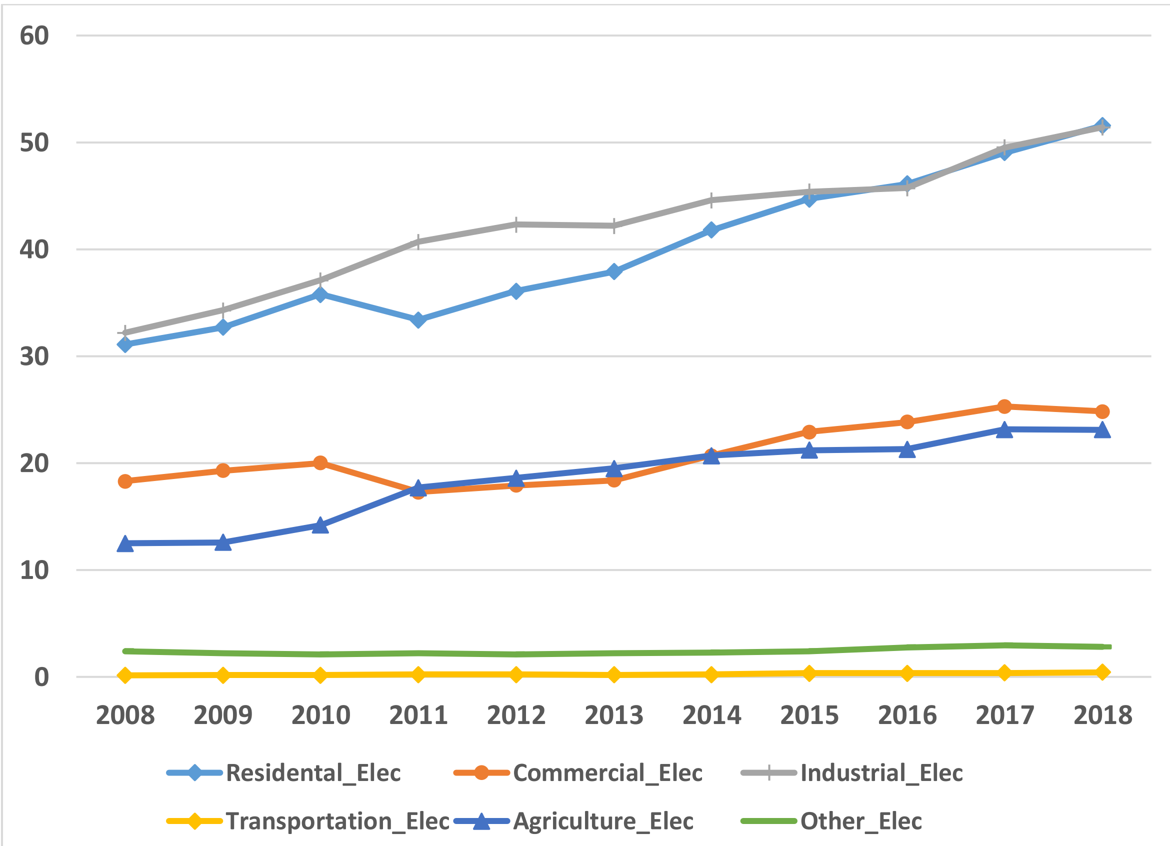

Fig 2. Electricity demand trend in different sectors (in terms of million barrels of crude oil)

The rest of the paper is organized as follows. Section 2 reviews the literature on the field of electricity demand forecast in the world. Section 3 describes the methodology used in this research and then, proposes a causal model of demand forecast. Furthermore, the state-flow model of demand forecast is designed and implemented for Iran in Section 4. The model and the scenarios related to the impact of subsidy are discussed in section 5. Finally, section 6 summarizes and concludes the discussion presented in this research.

2- Literature review

Huathaker (1951) conducted research, as one of the first attempts in this field, to predict power consumption, using the ordinary least squares (OLS) method (Kachoee et al., 2017). Azadeh et al. (2009) forecasted Iran's electricity demand monthly and proposed a hybrid approach, by combining time series, fuzzy inference system, and metaheuristic algorithm, aiming to minimize predictive error. In another study, Ardakani and Ardehali (2014) addressed long-term electricity demand forecast in developed and developing countries and used a combination of neural network and metaheuristic algorithm in order to forecast power consumption in the US, as a developed country, and Iran, as a developing country, until 2030. Mostafavi et al. (2014) estimated the power consumption in Thailand and considered factors such as population, gross product, stock indexes, and revenues from the export of industrial products in the electricity demand modeling by using the gene expression programming (GEP) method. Salmanzadeh-Meydani and Fatemi Ghomi (2019) researched on relation of electricity consumption, economic growth and capital stock in Iran. Yu et al.(2015) estimated power consumption on an annual basis based on various indicators including the level of economic development, industry structure, energy price, population, temperature, exports, and imports.

On the other hand, a large number of studies have been conducted on the prediction of power consumption to consider the effect of temperature variation on the electricity demand. For example, Felice et al. (2015) predicted electricity demand in different regions of Italy by considering the summer temperatures. In order to forecast Spain's electricity demand by 2030, Pérez-Garcia and Moral-Carsedu (2016) forecasted long-term electricity demand and identified effective factors in power consumption by using the decomposition model. In another study, Kaboli et al. (2016) estimated Iran's electricity demand. Based on various meta-heuristic algorithms, they optimized the coefficients of the importance of each effective variable and predicted electricity demand by 2030. Finally, as one of the recent works, Kachoyi et al. (2017), explained Iran's electricity demand by 2040 in three scenarios by using the econometric method. According to their prediction on power supply and demand, the reduction of carbon production and the growth of renewable energy will still be more than 90% of the power generation from fossil resources in each of the three scenarios in the current trend.

In all of mentioned researches, variables had one-way relations and there is no feedback in relations defined. Also social variables that have significant effect on electricity consumption were ignored. This ignorance has occurred in studies of developing countries due to lack of data and researches. Romm (2002) showed that there is a connection between the recent reductions of energy intensity and the astonishing growth in information technology (IT) and the internet economy. Court and Sorrell (2020) conducted the first systematic literature review of the direct and higher order impacts of the digitalization of goods on energy consumption.

2-1- Background of system dynamics in electricity demand forecasting

Since the supply and demand system of electrical energy has several factors and complex relationships, system dynamics is regarded as one of the methods used in the analysis of electricity demand, especially when there are non-linear and uncertain relationships between social and economic factors. This tool seems appropriate in the electricity demand forecasting, regarding the factors discussed in the reviewed articles. In this regard, Forrester can be considered as the founder of the system dynamics, who invented a method for fluctuations in production cycles at the GE home appliances manufacturing plant, which is known as "System Dynamics" todays (Klaus-Ole, 2004). The main idea of using the system dynamics in energy discussions was developed by Naill in 1972 to model American gas factories (Naill,,1972). In 1981, Stermann (1982) used this tool in his doctoral thesis in order to examine the relationship between energy and economics.

The article presented by Kayhan et al. (2010) is among the research, which used the system dynamics to forecast electricity demand predict. They examined the causal relationship between economic growth and power consumption in Romania during 2001-2010. In a similar paper, Kalyenko et al. (2013) studied the causal relationship between energy consumption (including electricity) and economic growth in three countries of Georgia, Azerbaijan, and Armenia. Mattew et al. (2017) reviewed the changes in electricity demand through carbon reduction and socio-economic development policies. For this purpose, the effects of variables such as tourists, electric vehicles, and energy efficiency on electricity demand in the long-term horizon were identified by using system dynamics. He et al. (2002) used system dynamics to predict energy consumption in the Tianjin region of China. In fact, they focused on changing the economic structure of the region and other factors to provide a prediction of power consumption. By examining the interaction between socio-economic factors and power consumption, Riva et al. (2018) evaluated the impact of access to electricity and rural development through system dynamics, in addition to addressing the effects of social variables such as social networks, education, and consumer habits.

Energy transformations occur in complex conversion processes involving a large number of actors and a highly uncertain future, leading to poor long-term planning, especially in quantitative modeling. Thus, the use of qualitative modeling with interpretive attitude can greatly overcome this uncertainty and the combination of quantitative and qualitative methods can be an appropriate approach in the long-term energy prediction. Moallemi and Malekpour (2018) explored this topic in practice in their research with an example of the developments in the electricity industry. Accordingly, the present study seeks to propose a quantitative-qualitative method for estimating electricity demand, which is explained in the following section.

3- Methodology

The power consumption system has different effective factors with various actors. On the other hand, the long-term electricity demand forecasting involves many uncertainties in modeling. For this purpose, interpretive-structural modeling was first used to identify the variables and their relationships based on experts' opinions. Then, we selected system dynamics as an appropriate tool to deal with the complexity of these relationships and utilize the qualitative method along with quantitative modeling.

3-1- Introduction to the method

In this research, a combination of integrated system dynamics (DS) and interpretative-structural modeling (IMS) was used, although less number of research has used these two methodologies. The first study was conducted in 1992 by Vizaykumar and Mohapatra to analyze the environmental impacts of coal mines, using the interpretive-structural model, as the starting point for the system dynamics model (Vizaykumar and Mohapatra, 1992). In the other article, Liu et al. addressed these two methods in the framework of their methodology. The results of interpretive-structural modeling were used for designing the system dynamics model in order to study the effects of urbanization on socio-economic indicators (Liu et al., 2011). Sushil (2018) derived the idea from the causal model of the system dynamics and the determination of the positive and negative relationships between variables while using the completion of interpretive-structural modeling. In fact, he used interpretive-structural modeling to construct the theory in information management and organization by adding polarity of relationships and loops.

First, the variables and their effective factors are identified and then the qualitative system dynamics is done in the second step (causal-loop diagram). These two steps are usually carried out by reviewing the literature and obtaining the opinion of the experts and ultimately, they are collected innovatively based on experts' opinion and the causal-loop diagram is plotted. On the other hand, according to a specific framework, the interpretive-structural modeling method integrates the variables and factors affecting the problem, after identifying systematically based on the questionnaire and experts' opinions, and determines the structure of the relations between the factors. This topic can be considered as the initial framework of the causal-loop diagram and directly introduces experts' opinions into the system dynamics model. Figure 3 demonstrates the overall process of this study, which is a combination of these two methods.

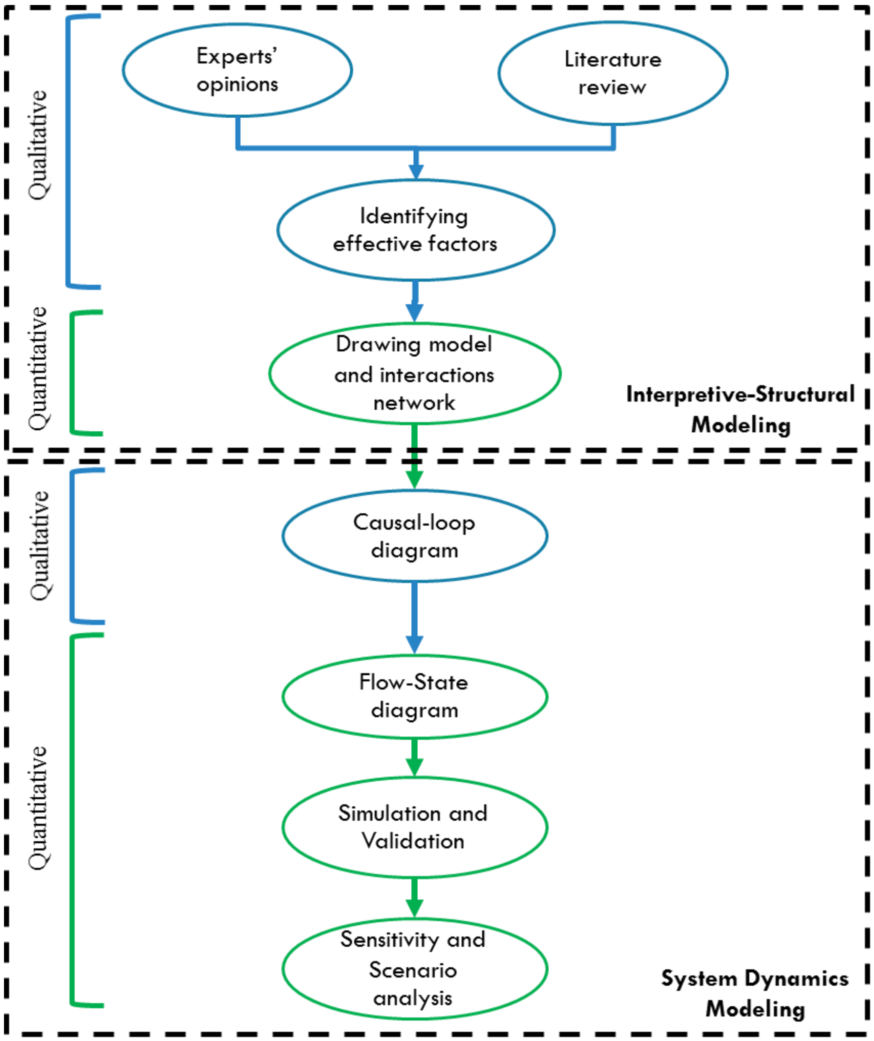

Fig 3. The process of conducting the present study based on the combination of the ISM and SD methods

As shown, the methodology of this research is implemented in two steps of interpretive-structural modeling and the system dynamics, which the details of each step are described below.

3-2- ISM model

Interpretive-structural modeling, which was first proposed by Warfield, is a methodology for creating and understanding the relationships between the elements of a complex system. This methodology greatly contributes to establishing order in complex relationships and is an interactive process, in which a set of different and interconnected elements are structured in a systematic and comprehensive framework (Sage, 1977). There are three main steps to implement the interpretive-structural model (Agarwal et al., 2007):

1. Identifying dimensions and indicators using subject literature
2. Determining the conceptual relationships between dimensions using the interpretive-structural modeling approach
3. Drawing the model and dimensional interactions network

3-2-1- Identifying dimensions and indicators using subject literature

So far, a large body of research has been conducted on the electricity demand forecasting, which was already discussed in the literature review section. Table 1 presents all factors reviewed in research, considering four studies conducted in this field.

Table 1. Factors used in Iran's electricity demand forecasting

Factors	(He, et al., 2017)	(Ghosh & Kanjilal, 2014)	(Riva, Ahlborg, Hartvigsson, Pachauri, & Colombo, 2018)	(Yu, Wang, & Wei, 2015)
Economic Growth	*	*	*	
Industrial structure	*			*
Power consumption per unit output	*			
Total energy consumption	*			
Stock index	*		*	*
Price factor	*	*		*
Energy conservation	*			
Power generation and transmission system	*			
Per capita consumption	*			
Number of residents	*		*	*
Number of electric equipment	*			
Maximum temperature	*			*
Per capita income	*		*	
Urbanization		*		
Education			*	
Habits			*	
Social networks			*	
Level of economic development				*

3-2-2- Determining conceptual relationships between dimensions

In order to re-evaluate the variables and to determine the relationships, the opinions of experts in the field of energy (in this paper, the experts of electricity and energy industry in Iran) about the factors affecting electricity demand were obtained through a questionnaire. In other words, the factors derived from the literature were presented and summarized and then, the matrix was obtained based on the following table and experts' opinions on the existence/non-existence of the relationship between the two factors affecting the determination of electricity demand. The number 1 implies the existence of a causal relation from the cause (row) to the effect (column) while the number 0 indicates the lack of a causal relation. The main diameter is considered one because the cause and effect is an agent.

Table 2. Matrix derived from experts' opinions

Reason \ Effect	Economic growth	Industrial structure	Energy price	Energy conversion and transmission efficiency	Power generation	Population	Urbanization rate	Number of electric equipment	Internet	People habits
Economic growth	1	0	0	0	0	0	1	1	1	1
Industrial structure	1	1	0	1	1	0	1	0	0	0
Energy price	1	1	1	1	1	0	0	0	0	0
Energy conversion and transmission efficiency	1	0	0	1	1	0	0	0	0	0
Power generation	0	0	0	0	1	0	0	0	0	0
Population	0	0	0	0	1	1	0	1	0	0
Urbanization rate	0	1	0	0	0	0	1	1	1	1
Number of electric equipment	0	0	0	0	1	0	0	1	0	0
Internet	1	0	0	0	0	0	0	1	1	1
People's habits	0	0	0	0	1	0	0	0	1	1

3-2-3- Drawing a model and dimensional interactions network

Based on the experts' opinions and drawing the received matrix (causal relations), the following diagram is obtained as follows:

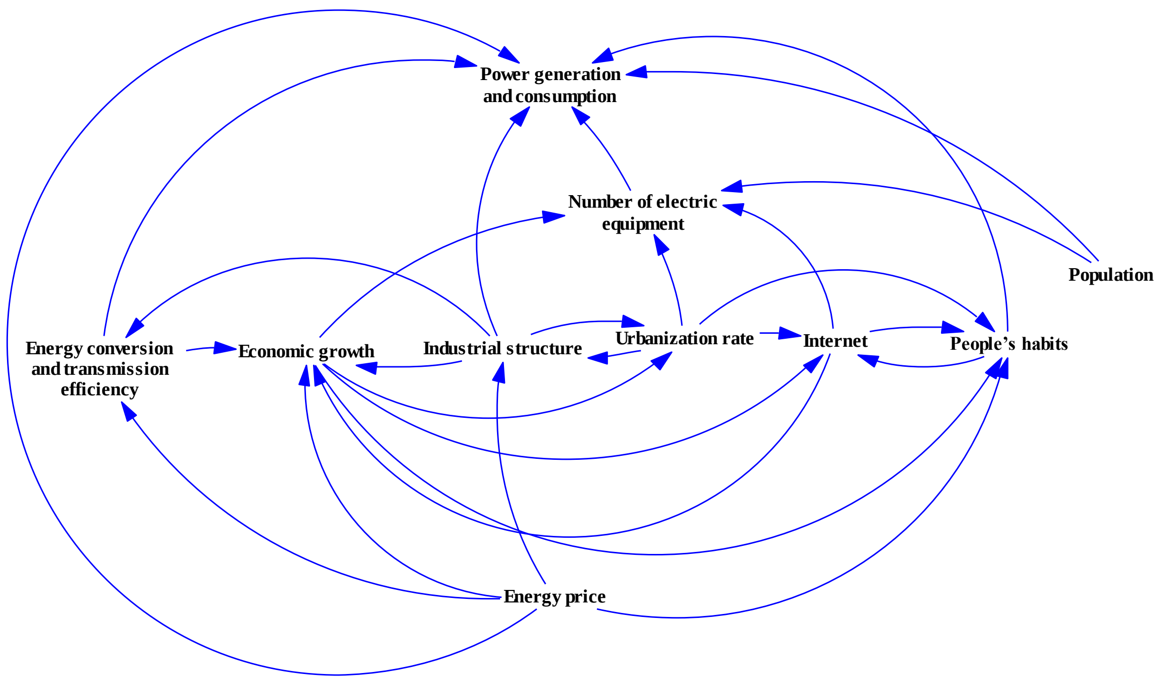

Fig. 4. Access matrix resulted from experts' opinions related to the relationship of factors affecting Iran's electricity demand

3-2-4- The form of matrix compatibility

Regarding the interpretive-structural modeling, the internal consistency of the matrix is evaluated and the matrix should become compatible in the case of incompatibility. In this regard, two methods have been suggested for compatibility. In the first method, experts' opinions are recollected and the access matrix is re-established while mathematical rules are used to create compatibility in the second method. In this method, the matrix is exponentiated to the power until compatibility is established, according to the Boolean rule. In this paper, the access matrix was modified based on experts' opinions and then, became compatible using the multiplication presented in the Boolean rule. The final matrix is illustrated in the figure 5.

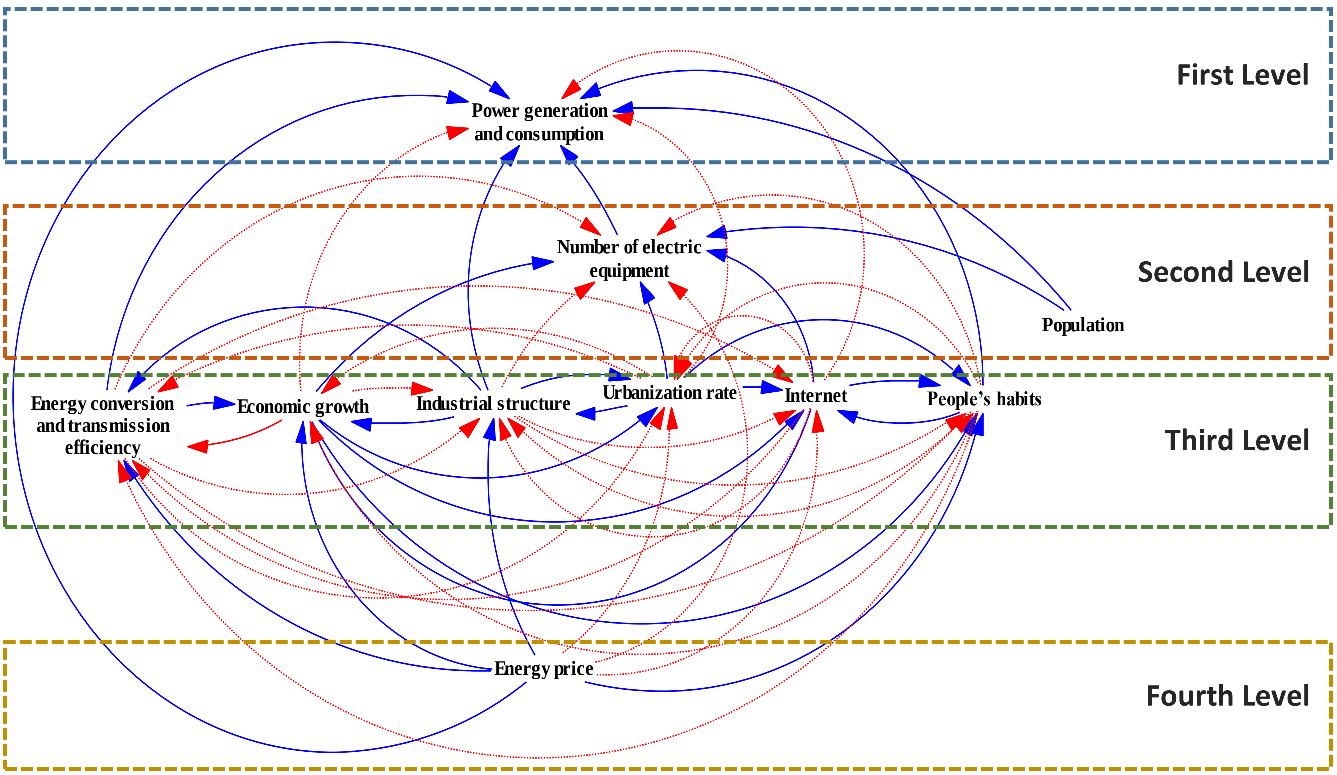

Fig 5. Access matrix of experts' opinions after compatibility

As depicted in figure 5, the matrix has a large number of relationships between different factors, indicating the complexity of evaluating power consumption. According to the above diagram, the added relationships and the compatibility of the access matrix are specified with the dotted red line. The definition of the access set of each element includes the variables, which can be obtained through that variable. The pre-requisite set contains variables through which this variable can be reached. The level of each variable can be determined based on the pre-requisite and access sets. A variable with the highest level has the same set of access set and common elements. After removing the variable/variables, the remaining variables are evaluated and the highest level is re-calculated and defined as the second level (Agarwal et al., 2007).

As shown in figure 5 variables were identified in four levels. The purpose of this study is to estimate electricity demand. This variable has lowest level that means it is effected by other variables. On the other hand, "Energy price" in fourth level is the key criterion with maximum driver powers. But in Iran, Energy price is not liberalized completely yet. So in this study, energy subsidy is used as energy price.
In the present study quantitative modeling should be performed based on the identified variables and their relationships. This issue can be implemented using the system dynamics and this methodology is based on the causal relationships between the variables and has the capability of quantization. System dynamics is used to estimate the electricity demand.

3-3-System dynamics model for electricity demand forecasting

3-3-1- The causal-loop model

Regarding the access matrix of experts' opinions and drawing the ISM diagram, the causal-loop diagram of the electricity demand forecasting is obtained as follows:

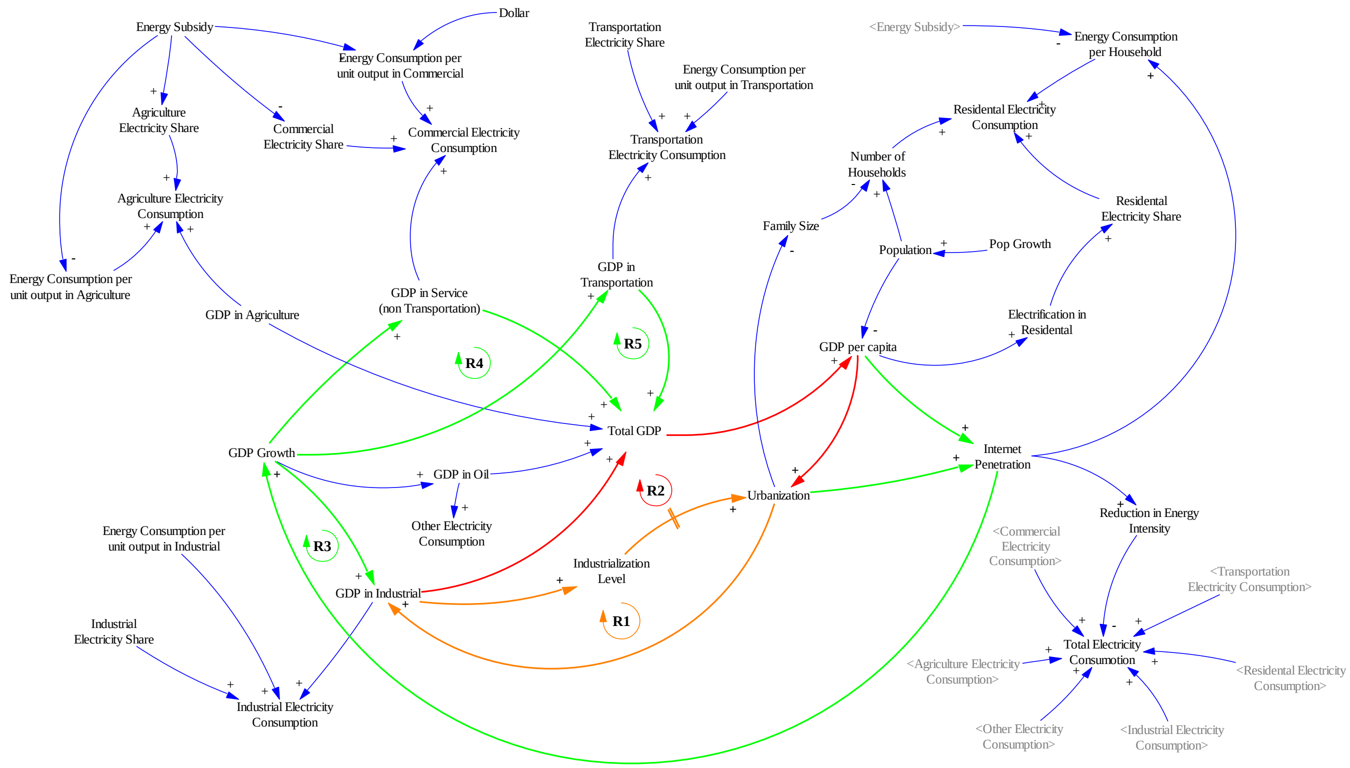

Fig 6. The causal-loop diagram of the electricity demand forecasting system

As observed, power consumption is considered in six different sectors including industrial, agricultural, service, residential, transportation, commercial, and others. The purpose of others is consumptions, which are not placed in the first five sections; for example, the consumption of power plants. It is worth noting that the process of designing the causal-loop model was performed based on the experts' views in Iran's power and energy industry. However, this method can be generalized to other countries and regions, based on local experts, and acquired a different causal-loop diagram, according to the steps described above. The next section describes the quantitative model for Iran.

In figure 6, five reinforcement loops are highlighted. R1 and R2 are related to urbanization and industrialization that improve each other and effect electricity consumption. R3, R4 and R5 related to effect of internet on GDP growth that called "internet economy", also Internet reduce energy intensity (Romm, 2002).

4- Case Study: Electricity demand forecasting for Iran

Iran, as a developing country with a growing population, has an increasing trend of energy consumption, such that electricity consumption has increased significantly with an average annual growth of 7.24% over the past two decades (Yousefi et al., 2017). In 1991, Fakhraei conducted one of the oldest estimations of electricity generation in Iran. He used the time series to forecast domestic power consumption in Iran. Despite the key role in development, electricity generation is the largest source of environmental pollution in Iran, where 30.2% of carbon dioxide production is related to electricity (Kachoee et al., 2017).

4-1- Iran's condition and power consumption status

Electricity generation in developed industrial countries is usually much higher than that of developing countries. For example, the average per capita annual production in the US in 2007-2011 was about 12,914 KWh per person, which is almost six times that proportion for Iran (Ardakani and Ardehali, 2014). Developing countries such as Iran should develop and grow their power generation capacity, due to industrialization and rural development, leading to the more use of electric equipment (IEA, 2011). On the other hand, considering the low level of power generation methods in Iran and the use of fossil power plants, the growth of electricity consumption has led to some concerns about the volume of using valuable fossil resources and environmental pollution. For these reasons, subsidies and prices related to energy carriers were modified in 2010 in other industries, in addition to the power industry. This issue has caused some changes in the consumption of an energy carrier (including electricity) and should be addressed in forecasting and making scenarios for electricity consumption (Ghosh and Kanjilal, 2014).

4-2- Data collection

The data required for modeling was derived from three main data centers as follows:

- Central Bank: Including information on the gross production of different sectors and exchange rates
- Ministry of Energy: Including information on production and power consumption in different sectors
- Statistical Centre of Iran: Including information on population, urbanization rate, and residents dimension

For prediction of Population in this study, the Growth rate was used from Hosseini research (Hosseini et al., 2019).

4-3-Agriculture sector

This section provides a prediction of power consumption in the agricultural sector as an example of the five steps used in this model. Power consumption is considered as a part of energy consumption, and therefore, it is necessary to pay attention to total energy consumption. Energy consumption is dependent on the production volume and the gross production of four main sectors and the residential sector are estimated based on the history of economic growth and the number of residents, respectively. Energy consumption can be defined by the following equation:

$$EnC_{it} = GDP_{it} * EP_{it} \tag{1}$$

Energy consumption (EnC) of sector i in year t is equal to the product of the gross domestic production (GDP) in per capita energy consumption per unit of production (EP). The per capita energy consumption will decrease with technological and productivity growth. Furthermore, increasing energy prices and encouraging savings will marginalize this variable, and consequently, the changes of a variable over time should be considered in the modeling process. According to historical data and regression model, per capita energy consumption of the agricultural sector was obtained by the equation (2):

$$EP_{Agriculture\ t} = 3.3037 - 0.0022 * t - 0.0088 * Energy\ Subsidy \tag{2}$$

Considering the negative coefficient t, it is known that the per capita energy consumption of the agricultural sector is decreased over time and with the growth of technology. The impact of energy subsidy is defined by a binary variable in such a way that this value is zero before 2011 and one after this time. The coefficient of this variable is negative, indicating savings due to rising prices for energy carriers. In order to forecast electricity demand, the electricity share is obtained from the total energy consumed according to relation (3). In this relation, the electricity consumption (ELC) of each sector is derived from the product of energy consumption (EnC) and the electricity share in the energy basket (ElS), which is dependent on time t. As an example, the start of the targeted energy subsidy law increased the tendency to use electric wells instead of wells with fossil fuels in the agricultural sector immediately.

$$ElC_{it} = EnC_{it} * ElS_{it} \tag{3}$$

The share of electricity consumption in the agricultural sector is obtained in accordance with historical data in equation (4). Regarding the changes of coefficients over time, the share of electricity in the energy basket of the agriculture sector has gradually increased, although the increased cost of energy increased the share of electricity by almost 14%. These equations were obtained for other sectors and applied to the state-flow model of the system dynamics.

$$ElS_{Agriculture\ t} = 0.022 * \mathrm{t} + 13.598 * \mathrm{Energy\ Subsidy} \quad (4)$$

4-4- State-flow model

Based on the causal-loop diagram and the collected data, the relationships discussed for the formulation were evaluated using SPSS software at the significance level of 5%, as presented in the previous section for the agricultural sector. The relations which were not statistically significant, were eliminated from the state-flow model. Considering the impact of the currency price on the gross production of the business sector, this variable was added to the model, in addition to the targeted energy subsidy variable. Figure 7 illustrates the state-flow diagram of electricity demand forecasting in Iran.

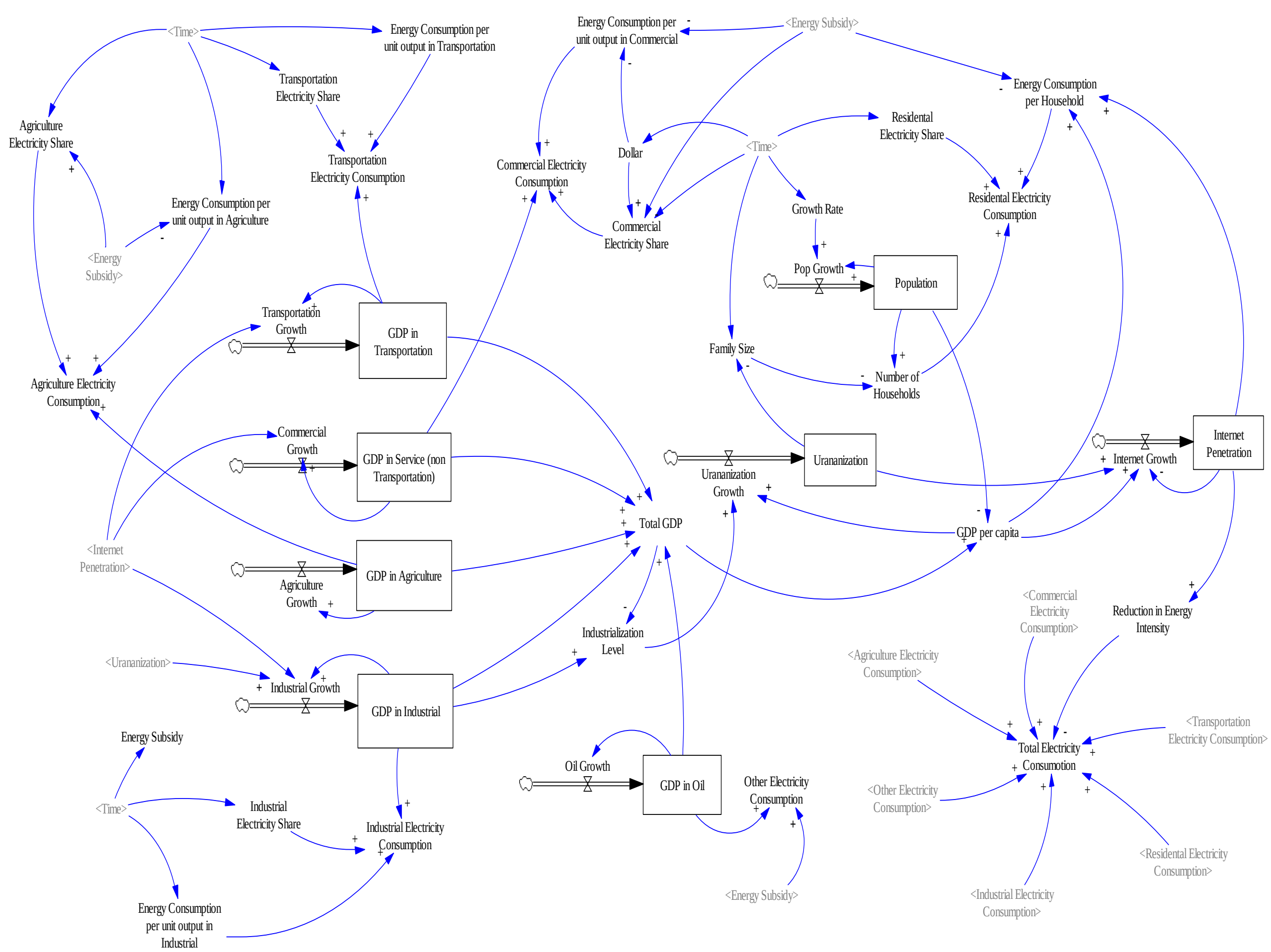

Fig 7. State-flow diagram for Iran's electricity demand forecasting

This diagram has eight state variables and has the ability to forecast Iran's electricity demand, based on the six sectors described in previous sections. These eight state variables are population, as well as the gross production of the oil sector, transportation sector, commercial sector, agriculture sector, industrial sector, urbanization and internet penetration. The last two items are socio-economic concepts that effect electricity consumption.

4-5- The results of the simulation

Figure 8 provides electricity demand forecasting during 2019-2038, considering the designed model and substituting numbers. According to the prediction, Iran's electricity consumption in 2038 would be 472 million barrels of crude oil, suggesting a 186% increase with respect to 2019. Additionally, the average annual growth of 5.7% in energy consumption is estimated in Iran for the next 20 years, although the growth of 7.1% has been experienced over the past two decades.

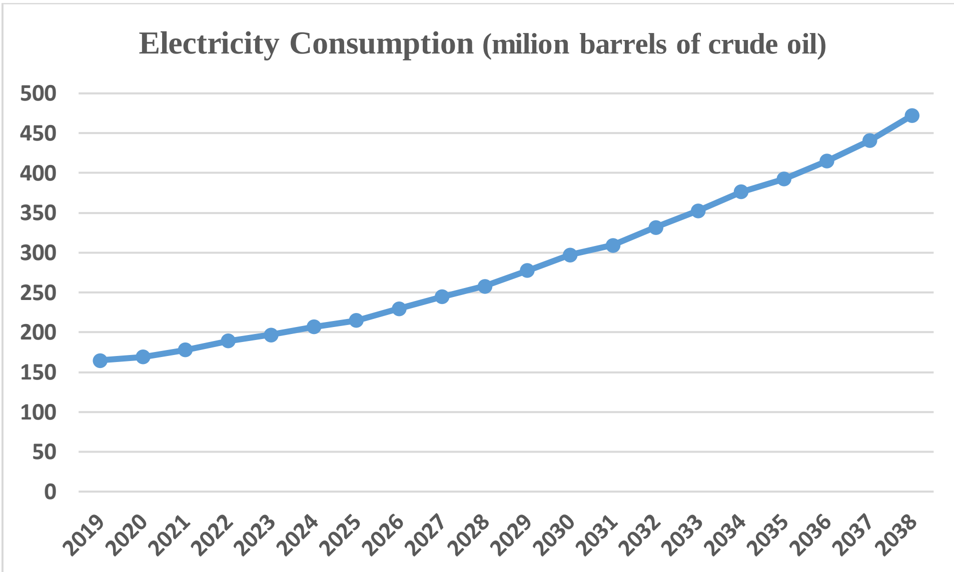

Fig 8. Electricity demand forecasting in Iran by 2038

5- Model evaluation and analysis

5-1- Predictive error

The years 2008 to 2018 were simulated as historical data and compared with actual values to test the model, which this comparison is presented in figure 9 and table 3.

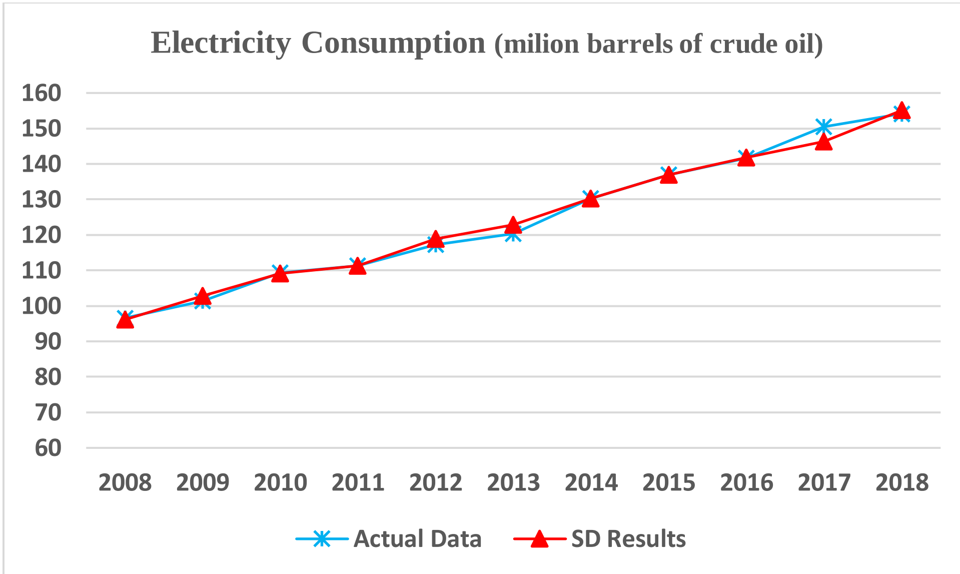

Fig 9. Comparing the actual and forecasted values of Iran's electricity demand

Table 3. Actual values and output of Iran's electricity consumption model (million barrels of crude oil)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Actual values	96.6	101.3	109.4	111.4	117.2	120.3	130.3	136. 9	141.7	150.4	154.2
Modeling results	96.1	102.8	109.2	111.3	118.9	122.9	130.3	137.0	141.8	146.3	155.1
Error percentage	-0.5%	1.5%	-0.2%	-0.1%	1.4%	2.1%	0.0%	0.0%	0.1%	-2.7%	0.6%

The highest error rate in estimation was at -2.7% for 2017. The mean absolute percentage error (MAPE) was used for the error criterion, which was the acceptable value of 0.84.

5-2- Compare to other researches

In this section, result of study is compared to other researches. Three researches with different methods have been selected. Koboli et al. (2016) used path-coefficient analysis to implement on logarithmic models to determine the optimized weighting factors. On this basis, Genetic algorithm is developed to provide better-fit solution and improves the accuracy of estimation that is called “logarithmic and GA”.

Salmanzadeh-Meydani and Fatemi Ghomi (2019) used the vector auto regression (VAR) model to estimate electricity consumption that is called “VAR”. The third study estimated electricity consumption by average growth that is called “constant growth” (Kachoee et al., 2017). The performance of the estimated methods is investigated and it clarifies that this research has the highest accurate estimation among four studies. The estimation and real data are presented in table 4.

Table 4. Percentage errors of electricity consumption estimation in 4 methods

Year	2012	2013	2014	2015	2016	2017	2018	MAPEs
Proposed	-1.4%	-2.1%	0.0%	0.0%	-0.1%	2.7%	-0.6%	**1.0%**
constant growth	3.4%	0.2%	2.2%	1.2%	-1.2%	-1.2%	-4.7%	**2.0%**
logarithmic and GA		0.0%	2.1%	3.0%	0.6%	3.9%	0.0%	**1.6%**
VAR	-10.6%	-13.5%	-11.1%	-11.3%	-13.5%	-13.0%	-16.6%	**12.8%**

5-3- Energy subsidies in Iran

In the late of 2010, the targeted subsidy law was approved in Iran, according to which subsidies were gradually removed from energy carriers and cash subsidies were provided to residents and different sectors. Hence, since the mentioned date, the price of electricity and most energy carriers have increased in most economic sectors, which will affect the amount of electricity consumption.

Figure 10 depicts the estimation of electricity consumption by 2038. As discussed in the introduction, the implementation of the targeted energy subsidy law in 2011 imposed different consumption trends to different sectors of the market. In addition, the factors affecting the consumption of each sector are distinct, leading to a different trend of electricity consumption in the coming years. This issue is evident in figure 10 since the highest energy consumption in the next two decades is related to the residential sector, according to estimations. The commercial electricity consumption has gradually lost the sensitivity to energy subsidy and indicates higher consumption growth compared to the agricultural sector.

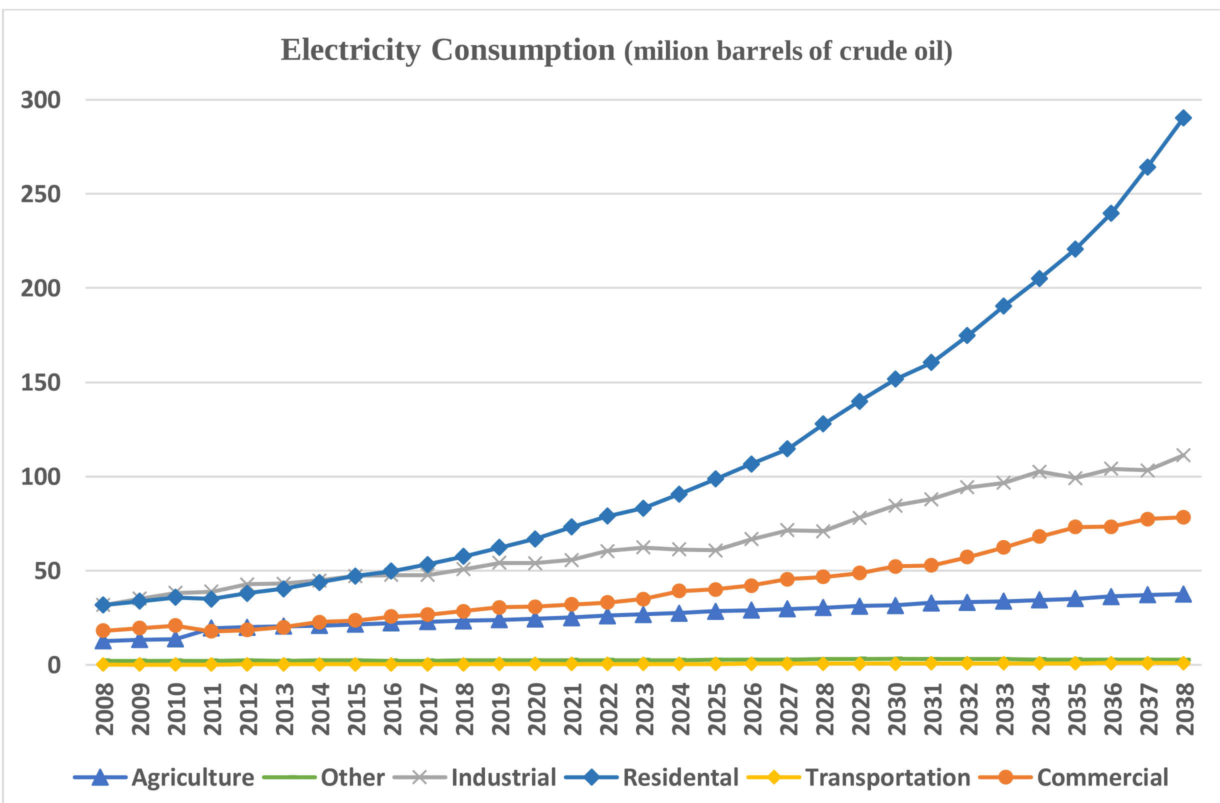

Fig10. The estimation of power consumption for each sector (equivalent to million barrels of crude oil)

As suggested, energy subsidy is defined by a binary variable, which is zero and one before and after 2011, respectively. This variable was identified significant in the agricultural, commercial, and residential sectors and ineffective in the industrial and transportation sectors. In order to investigate the effect of targeted subsidies, two scenarios were considered as follows: 1) the subsidy variable was considered zero in the whole year (No Subsidy), and 2) the effect of the subsidy variable was considered twice and the binary variable was determined two (Double Subsidy) since 2011. These two scenarios were compared with the default scenario in different sectors (Current).

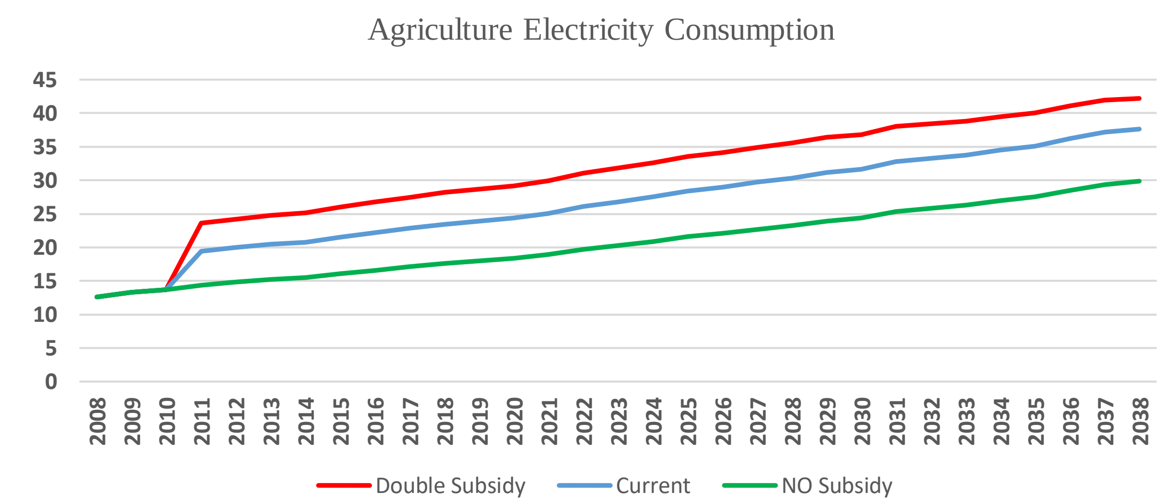

Fig11. The impact of targeted subsidies in the Agricultural sector

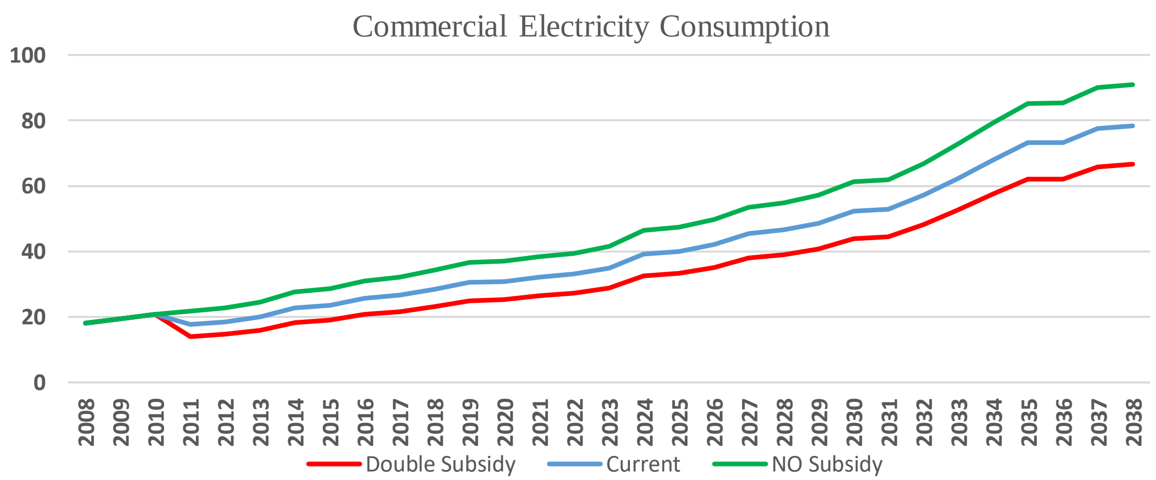

Fig 12. The impact of targeted subsidies in the Commercial sector

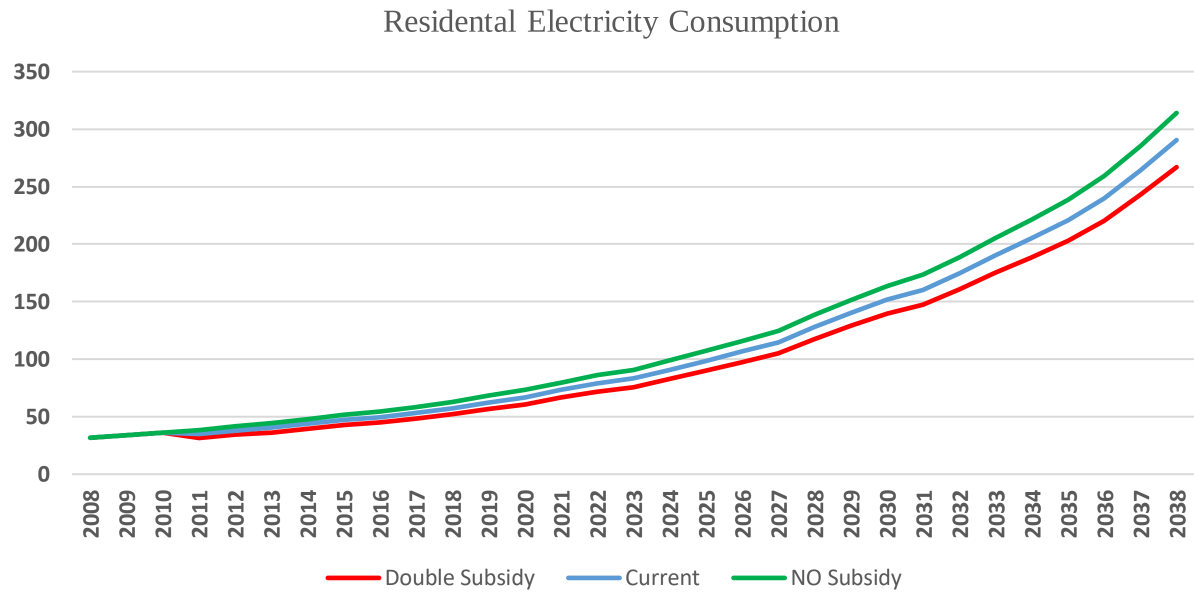

Fig 13. The impact of targeted subsidies in the Residential sector

As shown in figure 11, targeting subsidies has increased electricity consumption in the agricultural sector, due to the lower cost of this energy compared to other energies in the agricultural sector and its substitutability. The major power consumption in the agricultural sector is related to water wells, which can be converted from mechanical to electrical motors. Conversely, (As shown in figure 12-13) power consumption in the commercial and residential sectors has declined after targeting subsidies, which can be related to saving and reducing user's consumption. However, it is possible to change consumer habits in both of these sectors, by increasing the costs of electricity consumption and saving in advertising. In general, it is anticipated that about 6% of the country's electricity consumption will decrease through targeting subsidies by 2038.

6- Conclusion and suggestions

The present study aimed to provide a method for long-term electricity consumption in long-term horizons. Since various factors affect the power consumption and these factors are related to each other in a network of complex and non-linear interactions, the use of the statistical and time series methods alone cannot be useful to deal with challenges. Thus, this research first sought to use a method for reconsidering the factors affecting power consumption and provided the ability to model multiple and nonlinear relationships among factors. For this purpose, the interpretive-structural modeling and system dynamics were used for the first and second purposes and finally, the combined method of these two methodologies was proposed in this regard.

Then, the factors identified from the literature review were presented to the experts and the interactions network of these factors was identified qualitatively, using the interpretive-structural modeling. In the following, the network was considered as the starting point for system dynamics modeling and the causal-loop diagram was plotted consequently. Next, the long-term electricity demand forecasting model was designed by quantizing relationships. In order to test the model, Iran's electricity consumption was simulated from 2008 to 2018 in such a way that the average absolute error of this range was 0.84, which was evaluated as suitable. It should be noted that this model predicted Iran's electricity consumption by 2038. Regarding the importance of the targeted subsidy law, the impact of this law on power consumption was studied in different sectors of Iran's economy.

Finally, it is suggested that future research can address other factors such as the changes in people's habits, the impact of the culture of saving and protecting natural resources, in addition to economic drives. These variables may vary based on the circumstances of each country and should be examined according to the opinions of the experts of that country, similar to the method suggested in this paper.

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