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# The dynamics of substitution elongations between fossil fuel carriers in Iran: Policy guidelines for gas consumption in the industrial sector on the horizon 2025 using Kalman filter approach

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**Abstract**

The present paper explains the dynamics of substitution tensions between fossil energy carriers in Iran: Policy guidelines for gas consumption in the industrial sector on the horizon 2025 using the space model and Kalman filter approach for the years 2006-2019 in the form of quarterly data. Based on the model estimation results; Price and revenue elasticity of kerosene, gasoline, gas oil, furnace oil and liquefied petroleum gas -0.14, -0.07, -0.46, -0.10 and -0.24 and 0.48, / 06 0, 0.17, 0.48 and 0.01. Because the price elasticity of all four products is less than one, increasing the prices increases manufacturers' costs, and increasing costs slow down the pace of gas replacement. There is a direct relationship between sales tariffs and natural gas demand, which means that with a one percent increase in sales tariffs and liberalization of kerosene, gasoline, gas oil, fuel oil and liquefied petroleum gas prices; Gas demand respectively; 0.46, 0.34, 0.004, 0.17 and 0.11 will increase. As a result, natural gas is a stretchable commodity in the long run. Also, the highest price elasticity and substitution elasticity among petroleum products with natural gas up to the horizon of 1404, respectively; related to gas oil, furnace oil, kerosene, gasoline and liquefied petroleum gas. In other words, as a result of the implementation of the above policies, the share of crude oil in the initial energy supply has decreased from 89.5 to 42.5 percent. Furthermore, the share of natural gas has increased from 8.5 to 63.5 percent. As a result, the country is currently far from the goals set out in the document.

Keywords: Fossil energy carriers, gas consumption, industry sector, Kalman filter
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## 1 Introduction

It seems impossible to move toward economic development in the current world regardless of energy. Rather than playing its role as the main factor, energy is also assumed as a national income resource in our country. Thus, the

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necessity for moving toward economic development in our country; on the one hand, and the basic role of energy in this trend; on the other hand, represents the importance of identifying energy demand. The presence of plenty of gas resources in Iran and its low-cost and clean nature compared to other energy carriers have caused to plan for substitution of more than 70% of gas with other fossil energy carriers in the course of the IRI Economic Development Plan for 2025. To achieve this important objective, it necessitates for estimation of gas demand with respect to the potential for substitution with other energy carriers and investigation of the potential for realization of this national plan. Industrial countries possessed huge coal deposits in the past and it was also considered as the main energy resource. Following to industrial advancement of these communities, it was felt more need for energy and therefore industrial countries tended to substitute coal with oil. This energy enjoyed higher efficiency with lower extraction costs for this energy resource at that time and similarly, there were enormous deposits of this resource in the Middle East. For this reason, industrial nations replaced coal with oil. CNG was consumed at a higher scale in the countries, which produced CNG e.g. Russia, the USA, and regional states in the Middle East, after the occurrence of the oil crisis in years during the 1970s. Due to clean sources, ease of burning, higher heat value, and accessibility, the use of CNG has been also increased as an alternative fuel in other countries. It is expected that CNG to play a more prominent role in providing energy for the countries as a result of the rising demand for energy. The modern community asks for energy at a logical cost and with the destructive environmental effect as well as a fixed, available and permanent support. CNG has the highest share in achieving such objectives. As the cleanest fossil fuel in environmental protection and following the path toward optimal development, CNG has played an essential role and drawn more attention in Kyoto Summits and European Union (EU) concerning greenhouse gases [3]. Various studies show that carbohydrate sources will still remain the most major to provide energy resources by 2050. Analysis on the trend of these resources and their geographic distribution may indicate only five littoral states at the Persian Gulf, including the Islamic Republic of Iran, Saudi Arabia, Kuwait, Iraq, and UAE will remain as most major oil producers by 2025, and also Iran, Russia, Qatar, Saudi Arabia, UAE will be the main gas producers at that time. Similar to oil reserves, gas resources are divided into three classes of stabilized, probable and possible deposits and accordingly the size of fixed CNG reserves has been tripled during three recent decades. The quantity of these reserves has been increased from at about 50 trillion cubic meters in 1970 to more than 150 trillion cubic meters at the end of 2001. According to the existing report by the end of 2018, the amount of total gas reserves of the world is estimated about 187 trillion cubic meters where Russia with 48 trillion cubic meters has the highest amount of gas deposits and then Iran is placed at the second position with 34 trillion cubic meters of total world gas deposits [2]. Among gas reserves and exploited deposits existing in Iran, it is extraordinarily important to refer to two reserves of Maroon Makhzoomi Zone the southeast of Ahwaz and South Pars Project in Iran. In particular, South Pars is called the second and most important gas reserve in Iran that includes 50% of gas deposits in this country and about 8% of total world gas reserves have been concentrated at this zone. Similar to any input demand function, in order to derive gas demand function as an input, one could utilize both methods of derivation fro, profit function versus cost of inputs and or from cost function per any input price. The demand function is obtained directly in the first technique and demand functions are achieved indirectly or conditionally for input in the second method. The second has been obtained for extraction of demand function of inputs in most of the conducted studies. In this method, a production function is initially selected and its corresponding cost function is specified and then input demand functions are achieved by derivation from cost function versus the price of either of these inputs. Based on this technique, some factors are effective on CNG demand at household and trading sectors such as CNG actual price, price of other energy carriers, actual production in the economy and in the long run, renewal of structure at electricity and gas industry, demographic changes and centers in a country, energy efficiency rule and technological development. The volume of demand for CNG is always in periodic form; gas demand is further increased in cold months of the year than in hot months. The seasonal fluctuations of demand for CNG energy carriers are more related to temperature variations in household and commercial sectors. With respect to the relative abundance of gas reserves as well as lower environmental pollution of gas compared to other fossil fuels in the Iranian economy, it has been predicted to substitute it in most the industrial sectors of the country for 2025. Determination of elasticity for substitution of other energy carriers with gas time series is one of the foremost topics in this trend. To this end, it is tried in this paper to estimate gas demand function in the industrial sector using the Kalman filter algorithm. The rate of gas demand is forecast by 2025 based on the estimation model. Compared to the predicted quantity of gas and this amount in the National Development Plan Outlook, one could determine the percentage of realization of the National Economic Development Plan.

## 2 Theoretical fundamentals of the subject

Energy is seemed one of the important factors for economic growth and development in the current world and due to its important role in production and servicing costs as well as environmental issues, a lot of attention is paid to the improvement of consumption status and much more efficient to use it. Given the existing statistical data and information, whereas industrial sector is assumed as the foremost consumer of oil products in the national energy portfolio with rising growth; thus, paying attention to the management of energy consumption may enjoy a special position and importance in this sector. Inadvertent growth of energy consumption along with existing limitations for providing of demand from domestic products and or imports has caused the relevant executive references including the Oil Ministry to warn constantly about this trend and lack of providing for this quantity of demand both in terms of technical and financial and economic viewpoints. In the meantime, it is witnessed that financial burden of this quantity of imports has been highly increased every year. Alternately, world economic development needs the energy resources and various studies show that hydrocarbon resources will remain as the most major sources of energy supply by 2050. Review on the trend of these resources and their geographic distribution may indicate that only five littoral states in the Persian Gulf, including the Islamic Republic of Iran, Saudi Arabia, Kuwait, Iraq, and UAE will remain as most major oil producers by 2025 and also Iran, Russia, Qatar, Saudi Arabia, UAE will be the main gas producers at that time. Due to high income per capita and the potential for the use more various energy-consuming devices and equipment, the amount of energy use per capita is usually higher in advanced and developed communities. At the same time, the rise in productivity has been led to the mitigation of energy consumption in these countries during recent decades. The final energy consumption rates per capita at agriculture, household, public and trade, transportation and industrial sectors in Iran have been increased 3.1, 1.8, 1.5 and 1.4 times greater than the world average rate respectively in 2018. Comparison of final energy use per capita in Iran separately based on energy carriers with world-scale may show that the rate of final energy use is higher than world average use and this trend results from lower productivity in utilization, higher energy consumption and also use of energy-consuming goods and services. Many positive efforts have been made to convert CNG into the dominant fuel in the national energy consumption portfolio. The majority of such measures were allocated to household-commercial, industrial and power plant consumer sectors, but it seems there is still some potential to substitute CNG in the industrial sector. The importance of this subject may be more observable especially with respect to the fact that the highest subsidy of the energy sector has been allocated to the industry and transportation sector in Iran. The industrial sector is the most intensive consumer for oil products including kerosene, gasoil, and fuel oil where replacement of this amount of oil products with CNG may noticeably reduce the imposed costs to the national economy at this sector in various dimensions. On the other hand, today air pollution is seemed as one of the paramount environmental problems in Iran. Some factors e.g. fast population growth in megalopolises, transport of more than 16 million vehicles in the country in 2019, rising consumption of fossil fuel, improper transportation model and existing industries have increased air pollution in Tehran and other Iranian metropolises. Discussion about the use of alternative fuels is not a new subject in today's world. Most of the world countries consider diversification in consumed fuel portfolio in the industrial sector as strategic issues based on national (e.g. independence from oil in the Middle East), environmental (e.g. propagation of pollutant gases), social (job creation by the production of alternative fuels) and or economic interests (e.g. low cost of such fuels) today so that according to the weight designated for each of above-said factors, about 15-20% of this share is specified to the alternative fuels. It is obvious that by putting this type of fuels beside traditional fuels e.g. gasoline and gasoil, CNG and fuel oil this is led to technological upgrading in the industrial sector and enhancement at the level of social culture rather than diversification as well. CNG fuel has been used as one of the alternative fuels with regard to the abovementioned topic for several years. This trend possesses an intrinsic advantage for possession of CNG reserves in countries with gas deposits and also it possesses a high economic advantage in some countries adjacent to the world gas market. As a result, the use of natural gas as Compressed Natural Gas (CNG) or Liquefied Petroleum Gas (LPG) is not economically comparable with consumption of natural gas in many countries at present, but most of technological factors have still caused not to present this main fuel along with gasoline and gasoil in transportation fleets. The unprecedented technological developments in this industry in the world and the rising expansion of this trend in most countries that are mainly due to its economic advantages have caused to accelerating development trend of CNG in Iran. Although passing over legal bars and investment barriers were primarily very difficult, following a lot of efforts, the appropriate legal, national, and executive grounds were finally prepared for this measure so that continuance of this trend might be very beneficial for the advancement of the final objective and it has been predicted this replacement is done in most of the industrial transportation, services, and household sectors by 2025.

### 2.1 Review on the dynamism of substitutive elasticity between fossil energy carriers in Iran

CNG is consumed at a higher scale in CNG producer countries including Russia, the USA, and Middle East countries after the advent of the oil crisis in the 1970s. Due to cleanness, ease of fuel consumption, high thermal value and availability, CNG use has been also increased in other countries. It is expected that CNG play a more prominent role in energy supply for the countries as a result of the rising demand for energy. Given the plenitude and dispersion of gas reserves in Iran, lower costs for extraction, refinement, processing and transfer of gas versus oil, viability and capability for using of CNG reserves up to three forthcoming centuries, relatively low and competitive price with respect to its thermal energy, providing comfort for families and enterprises because of ease of access and continued availability, lower environmental pollution compared to other fuels, enormous saving of foreign currency by replacement of other fuels with CNG, including kerosene, gasoil, fuel oil and petrol, non-energetic uses in oil and petrochemical industries by feeding into oil reserves and conversion of gas into various commodities and many other advantages and benefits, we can find the important position and role of CNG at present and particularly in the future as one of the main energy providers needed for different consuming sectors in the country. Substitution of low cost and eco-friendly energies with oil products by developing gas transfer network, conversion of other fuels used in power plants and large industries into CNG and consuming of Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) as the fuels for vehicles and administration on supply and distribution of oil products are considered as most important done and or under implementation by energy supply management in the country. We use the Trans log production function to obtain the crossover price elasticity of CNG instead of oil products. Rather than lack of aforesaid constraints in Trans log functions, the given empirical results have shown that these functions are highly fitted for energy models. Trans log functions are second order compared to the logarithm of values of inputs and outputs. As the consequence, if 6 main factors, including natural gas (GAS), gasoline (BEN), kerosene (KER), gasoil (GOI), fuel oil (FOI) and liquefied petroleum gas (LPG) are utilized each of their prices $(P_{GAS}, P_{BEN}, P_{KER}, P_{GOI}, P_{FOI}, andP_{LPG})$ in cost function then Trans log cost function will be expressed as Eq. (2.1), as follows:

$$\ln TC = \alpha_0 + \alpha_Q \ln Qt + \sum_i \alpha_i \ln p_{it} + \frac{1}{2}\sum_i\sum_j \alpha_{ij} \ln p_{it} \ln p_{jt} + \sum_i \alpha_{iQ} \ln p_{it} \ln Qt + \frac{1}{2}\alpha_{QQ}(\ln Qt)^2, \quad i = GAS, BEN, KER, GOI, FOI, LPG \tag{2.1}$$

where, TC denotes gas energy consumption expenses, and $Q$ is the added-value in the gas sector. Some assumptions should be utilized for the above-said model to analyze Trans log energy function, including:

1. Weak separability: It is assumed in this state that the final rate of substitution is independent between various energy carriers. Consequently, any type of substitution between various energy carriers in Eq. 2.1 will not affect other production factors.
2. The neutrality of technical changes: If technical changes have no impact on consumption or saving of input we can say these changes are neutral.
3. Constant-return-to-scale: The functions with constant return possess marvelous theoretical property versus scale based on which the negative final return-to-scale (RTS) only depends on two inputs between factors among inputs not on product scale.
4. Homogeneity of trans log function versus prices:

$$\sum_i \alpha_i = 1, \sum_i \alpha_i j = \sum_j \alpha_{ji} = \sum_i \alpha_{iQ} = 0 \tag{2.2}$$

5. The drivability of first- and second-order trans log function.

The parabolic structure of this function will be obtained by implementation of above-said hypotheses and acquisition of first and second-order derivative of trans log function. The parabolic functions for each of the cost factors are expressed as Eq. (2.3):

$$S_i = \alpha_i + \sum_j \alpha_{ij} \ln p_j + \alpha_{iQ} \ln Q \tag{2.3}$$

Where, $S_i$ is cost share of production factor $i$. implementation of above-said assumption will be accompanied with the following result:

$$\sum_i S_i = 1, \text{i= Different energy products} \tag{2.4}$$

With respect to the given constraint, it is enough to estimate (n-1)th equation from parabolic equations and to compute nth equation with respect to given constraints in the function. Using Shepherd,s lemma for estimation of return of cost function coefficients, firstly the equations are derived for a share of cost function and then their coefficients are obtained using the Kalman filter. According to the theorem of Shepherd,s lemma, the optimal demand can be extracted for production input at minimum cost level by derivation from cost function; namely:

$$X_i = \frac{\partial C}{\partial p_i}, \frac{\partial \ln C}{\partial \ln p_i} = \frac{\partial C}{\partial p_i}.\frac{p_i}{C} = \frac{p_i X_i}{C} = S_i. \tag{2.5}$$

The given formula is utilized in trans log functions to calculate substitution elasticity between various inputs after estimation of model coefficients and also price elasticity of factors:

$$\alpha_{ji} = \frac{\alpha_{ji} + S_i S_j}{S_i S_j}, i \neq j, i, j = \text{Different factors of production}, \alpha_{ii} = \frac{\alpha_{ii} + {S_i}^2 - S_i}{{S_i}^2}. \tag{2.6}$$

The probable modes in Eq. (2-6) are:

1. If $\alpha_{ij} > 0$, then it can be concluded that inputs i and j are substitutes to each other;
2. If $\alpha_{ij} < 0$, then it is followed that inputs i and j are complements to each other;
3. If $\alpha_{ij} = 0$, it can be concluded that there is no relationship between two inputs i and j.

The price elasticity of inputs can be computed according to Eq. (2.7):

$$\epsilon_{ij} = \alpha_{ij}.S_j, \epsilon_{ii} = \alpha_{ii}.S_i. \tag{2.7}$$

As a result, based on the formula at above, price elasticity rates will be as follows:

$$\epsilon_{ij} = \frac{\alpha_{ij} + S_i S_j}{S_i}, \epsilon_{ii} = \frac{\alpha_{ii} + {S_i}^2 - S_i}{S_i}, i, j = \text{Different factors of production}. \tag{2.8}$$

The econometric technique is utilized to estimate dynamic substitution elasticity by variable regressions with time series and using the Kalman filter. Kalman filter calculates estimations out of real values of parameters in time series by employing input data and mathematical process model. This technique may be noticed in the form of the easiest dynamic grids. Kalman filter has been developed based on estimation of State Space models originally used for engineering and chemical applications. In the 1980s, researchers started to employ this technique in the economy. According to these statements [7], two main types of models are suitable for presentation by Kalman filter: 1- Invisible Element Model; and 2- Models of variable models when it is dealt with the analysis of the model of variable random parameters in time series for modeling in details.

### 2.2 Research literature

In a study done by [12], they explored the effect of substitution of CNG and transferring of energy use structure in China using a dynamic model of energy substitution system. Their findings indicate that enormous coal capitals and oil potentials may effectively delay the development of CNG substitution for optimization of energy structure and as a result, it may create limited impact by replacement of CNG at short term and high cumulative effect at long term. Further analysis of this scenario shows that CNG subsidies and carbon price related policies may positively affect the growth of CNG consumption and optimization of energy structure. The findings also indicate that it is possible to create more pressure by security for providing of demand of energy consumption in transferring energy. Some recommendations have been presented to improve the structure of energy use in China at three dimensions: Allocation for investment in CNG, reduction of cost for transferring CNG with other energy resources and awareness of systemic risks in consumption of energy. In a survey conducted by [1], they modeled demand for industrial energy in Saudi Arabia using Harvey's (1989) Structural Time Series Model for a time interval (2010-2016). Their findings indicate that Saudi Arabia executed an intensive plan for correction of energy price in 2016 that led to rising prices of electricity, fuel and water for the household sectors and industries. The findings of their analysis show that the higher prices of industrial energy in 2016 might reduce 6.9% in energy use in this sector by fixing all of the other factors and it was decreased about 0.3% compared to the previous year. Therefore, Saudi policymakers may try to reduce the growth rate of industrial energy use and improve economic productivity and preserve their competition in the sector of industries based on a current corrective policy of energy price and energy productivity standards.

In a study carried out by [8], they estimated the performance of gas demand in residential and industrial cities in the Korean Republic using the Kalman filter within a time interval (1998-2018). Similarly, the price of demand was estimated for urban gas with a pull rate of inelastic income because their absolute values were less than the unit in time series. The absolute values are estimated for price elasticity and revenue in the housing sector greater than for gas in industrial cities; therefore, consumers of urban gas will probably further respond to gas in the industrial cities than the variance of housing price and revenue. There is a remarkable effect of revenue on demand for residential urban gas in Korea while the industrial urban gas includes relatively small price and income effects. The findings of this study may provide a method of Kalman filter for the policymakers to access more precise information about flexibility potential for performance of demand of urban gas that may vary over time.

In an investigation done by [6], they estimated demand for gasoline in Iran within a time period (1995-2017) using state-space representation model and resulting denotations for release of their price. The findings for model estimation suggest that gasoline price elasticity has varied during the studied period and the absolute value of gasoline price elasticity increased after execution of Targeting of Subsidies Plan (2010-2017) in some seasons of the year while it was decreased in other seasons of the year. It was predicted with three different scenarios at any year that unlike what expected, demand for gasoline would not be decreased by 10% increase in gasoline price during the 6th National Economic Development Plan and at the same time whereas the absolute value for gasoline price elasticity was greater at the beginning of 6th National Economic Development Plan and lesser at the end of this plan, then the rate of increase in gasoline price should not be the same during this plan. For this reason, it is recommended to planners and policymakers for controlling of gasoline demand to determine rise of gasoline price more than 10 percent at 6th National Economic Development Plan and such a rise in price should be ascending from the beginning of the plan to the end.

In their survey, (9) studied seasonally on the effect of the release of CNG price on tolerance of Iranian CNG distribution system in the household sector during the period (2005-2017) and took Variable Auto-Regressive approach using Johansen-Julius Cointegration method with Variable Error Correction Method (VECM). Based on Instant Reaction Factors (IRFs) of impulse caused by real price of CNG versus Lyapunov exponent as tolerance parameter for CNG distribution system, it is shown that Lyapunov exponent decreases in short term and it increases and its effect will be fixed in long run. The results of Variance Decompositions (VDCs) may indicate that CNG price possesses more shares in explanation of error of estimation for Lyapunov exponent, but this share will be reduced in the long run. Based on the results of the estimated model (VECM), although CNG price has positively affected tolerance of gas transfer system before execution of Subsidies Targeting Law, it was led to a reduction in tolerance of gas transfer system after performance execution of Subsidies Targeting Law.

In their study, [6] estimated demand for oil products using state-space representation mode and the given denotations to release their prices during years (1994-2017). The research findings indicate that the price elasticity of oil products has varied during the studied period. Using three different scenarios, it is estimated that with 10% increase during 6th National Economic Development Plan, the price of oil products has been reduced for consumption of kerosene and fuel oil every year, but unlike what expected, consumption of gasoline and gasoil was increased. Thus, the motive for saving in the use of kerosene and fuel oil increased and it was reduced for consumption of gasoline and gasoil among consumers. Following to 10% increase in their price during 6th National Economic Development Plan, forecasting of price elasticity for all four products indicated that unlike as expected, the absolute value of gasoline price elasticity was reduced and consumption of kerosene, gas oil and fuel oil was increased. Therefore, in order to stimulate sensitivity in gasoline consumers to rising prices, the release of their prices should be accelerated more at the end of the 6th National Economic Development Plan than the beginning of the plan for products of kerosene, gas oil and fuel oil at the start point of plan greater than the end of this plan. Given that in the already conducted plans, the problem of the present research has not been directly addressed, the current study investigates complementarily dynamic mechanisms for substitutive elasticity between fossil energy carriers in Iran along with these studies namely policy-related guidelines for gas consumption in the industrial sector by 2025. Due to the dependency of the Iranian economy on oil, the findings of the present study may contribute to clarifying this subject that whether the findings of this study are consistent with the results of previous studies inside the country and abroad. We will analyze these findings by the design of Kalman filter and State-Space Representation model for Iranian economy by seasonal data and within a period (2016-2020). Thus, the initiatives of this study can be mentioned as follows: Firstly, it includes a more comprehensive study period than in previous studies. Secondly, the reliable and more realistic results could be presented in the current paper by conducting accurate analysis on characteristics of studied data and way of their effects as well as employing the most valid econometric techniques proportional to these features.

## 3 Methodology

Following the studies done by [12], [1], [8], and [6], the dynamism of substitution elasticity will be analyzed between fossil energy carriers in Iran in this investigation: Policy related guidelines for gas consumption in the industrial sector by 2025-development outlook. As also implied in the section of theoretical fundamentals, we will utilize Trans log function to obtain the crossover price elasticity of CNG instead of oil products. Rather than lacking of given constraints, the resultant empirical findings have been shown in Trans log functions which are highly fitted for energy models. Trans log functions are the second-order versus logarithm of values of inputs and outputs. Consequently, if 6 main production factors, including CNG (GAS), gasoline (BEN), kerosene (KER), gasoil (GOI), fuel oil (FOI) and liquefied petroleum gas (LPG) are utilized in cost function and their prices are $(P_{GAS}, P_{BEN}, P_{KER}, P_{GOI}, P_{FOI}, and P_{LPG})$, then Trans log cost function will be expressed as Eq. 3.1:

$$lnTC = \alpha_0 + \alpha_Q lnQt + \sum_i \alpha_i SV lnp_{it} + \sum_i \alpha_1 d_{it}, i = GAS, BEN, KER, GOI, FOI, LPG \tag{3.1}$$

where, TC stands for gas sector energy expenses; and $Q$ the added value in the industrial sector. (P) Denotes the price of oil products and d indicates dummy variable for release of price of oil products and release tariff rate in 2011. Likewise, the time interval is shown as seasonal data from 2006 to the second quarter of 2020 in this study and the studied data have been collected from the published statics and figures by the Ministry of Energy and National Iranian Oil Products Distribution Company (NIOPDC).

State-Space Representation model has been utilized in this study along with time-variable random parameters in linear regression in which price elasticity and substitution elasticity coefficient vary over time. Detailed presentation of the dynamic system written in the State-Space representation should be expressed suitably for Kalman filter. The following system including State-Space Model with the dynamism of $Y_t$ and $n_{X1}$ vectors is designated for the following system of equations.

$$Y_t = AX_t + H\epsilon_t + w_t. \tag{3.2}$$

Eq. 3.2 is known as the observation equation; $Y_t$ denotes $N1$ observations of the dependent variable that is gas demand variable, A is $kn$ matrix for the observations of dependent variable namely gas demand variable. A is the $kn$ matrix for the observations of exogenous variables (gas price, oil price, income etc.), $X_t$ is the K-I vector for unknown parameters, $\epsilon$ vector on invisible variables, $V_t$ and Wt are the disruption elements in state and observation equations either of which is independent and co-distributed and also $E(V_1, W_2')$ signify lack of dependence between $W_t$ and $V_t$.

$$E(V_t, V_T') = \begin{cases} Q, & t = T \quad (3.3) \\ 0, & \text{otherwise} \quad (3.4) \end{cases}$$

$$E(W_1, W_2') = \begin{cases} R, & t = T \quad (3.5) \\ 0, & \text{otherwise} \quad (3.6) \end{cases}$$

where $Q$ and $R$ denote $rxr$ and $nxn$ matrices, respectively.

The recursive algorithm is utilized in the Kalman filter method to calculate predictions of least linear squares of state vector based on the observable data within previous periods.

$$\begin{aligned} \hat{\epsilon}_{t+1|t} &= E(\epsilon_{t+1}|\epsilon_t), \\ \hat{\epsilon}_t &= E(y_t', y_{t-1}', ..., y_1', x_t', x_{t-1}', ..., x_1'). \end{aligned} \tag{3.7}$$

Kalman filter computes these predictions in recursive forms.

$$\hat{\epsilon}_{1|0} \to \hat{\epsilon}_{2|1} \to ... \to \hat{\epsilon}_{T|T-1} \tag{3.8}$$

and at any phase of prediction, Mean Square Error of Estimation (MSE) can be calculated as well.

$$P_{1|0} \to P_{2|1} \to ... \to P_{T|T-1}. \tag{3.9}$$

The $p(1|0)$ and $\epsilon(1|0)$ are the start points for the prediction of such an algorithm that:

$$\hat{\epsilon}_{1|0} = E(\epsilon_1)P_{1|0} = E[(\epsilon_t - E(\epsilon_t))(\epsilon_t - E(V_t))']. \tag{3.10}$$

If $F$ eigenvalues are located within the same cycle, the $\epsilon_t$ process is a static covariance process. At this mode, the unconditional mean value $\epsilon_t$ is obtained by this expression $\epsilon_{t+1} = FE(\epsilon_t)$ and we have:

$$(I_2 - F)E(\epsilon_t) = 0. \tag{3.11}$$

If the eigenvalue of $F$-matrix is not the unit (1), $(I_2 - F)$ is non-singular and this equation has the specific root. $E(\epsilon_t) = 0$ The unconditional variance $\epsilon_t$ is derived from the following formula.

$$\begin{aligned} E(\epsilon_{t+1}, \epsilon_{t+1}') &= E[(F\epsilon_t + V_{t+1})(F\epsilon_t + V_{t+1})'] \to \\ E &= FE(\epsilon_t\epsilon_{t+1}')F' + E(V_{t+1} + V_{t+1}'). \end{aligned} \tag{3.12}$$

By calling variance-covariance matrix $\epsilon$ to $\sum$, we have:

$$\sum = F\sum F' + Qvec(\sum) = [I_{r^2} - (F \otimes F)]'vec(Q). \tag{3.13}$$

Then at this mode, if F-eigenvalues are excluded from the singular cycle, iterations of Kalman filter can start from $\hat{\epsilon_{1|0}}$, $vec(P_{1|0}) = [I_{r^2} - (F \otimes F)]'vec(Q)$.

The calculated Kalman filter is built within the linear representations. Among a group of predictions, which are linear based on $x_1$ and $\epsilon_1$, prediction of $\hat{y}_{t|t-1}$ and $\epsilon_{t|t-1}$ is optimal provided initial state of $\epsilon_0$ and disruption elements ($w_t$ and $v_t$) are normal multivariate for each t from 1 to T.

$$y_t|x_t, \epsilon_{t-1} \approx N(A'x_t + H'\epsilon_{t|\hat{t}-1}, H'P_{t|t-1}H + R). \tag{3.14}$$

A more rigid claim can be proposed and it is that prediction of $\hat{\epsilon}_{t|t-1}$ and $\hat{y}_{t|t-1}$, which has been computed by Kalman filter, is optimal among all $(\epsilon_t, x_t)$ functions. In addition, if ($\epsilon_0$ and disruption elements ($w_t and v_t$) are normal for each t from 1 to T, the conditional distribution of $y_t|x_t, \epsilon_{t-1}$ is obtained with a mean value of $A'x_t + H'\hat{\epsilon}_{t|t-1}$ and variance $fH'P_{t|t-1}H + R$, namely:
The probability density function is derived based on the above-said distribution:

$$f_{y_t|x_t,\epsilon_{t-1}}(y_t|x_t, \epsilon_{t-1}) = (2\pi)^{-\frac{\pi}{2}}|H'P_{t|t-1}H + R^{-\frac{1}{2}}|exp(-\frac{1}{2}(y_t - A'x_t + H'\epsilon_{t|\hat{t}-1})(H'P_{t|t-1}H + R)^{-1}(A'x_t + H'\epsilon_{t|\hat{t}-1})), \tag{3.15}$$

where, this formula satisfies per $t = 1, 2, \ldots, T$. Accordingly, one could obtain the following expression by calculation of logarithm in both sides and sum value for all $t$:

$$\sum log(f_{y_t|x_t,\epsilon_{t-1}}(y_t|x_t, \epsilon_{t-1})). \tag{3.16}$$

The necessary estimation could be obtained for F, Q, H, A and R matrices by numerical maximization of this formula based on existing unknown elements in this expression and this may be done using various software packs. A linear trend is considered as random or constant with slope and intercept. The observation and state equations will be as follows at this mode: The other technique is to divide unobservable factors as a trend and seasonal (quarter) elements. Whereas used data possess monthly frequency in this mode, the seasonal element (time component) will be converted into 12-order self-descriptive process. The trend elements could be also written as an element as follows:

$$\sum_{t=1}^{T} log(f_{y_t|x_t,\epsilon_{t-1}}(y_t|x_t, \epsilon_{t-1}))log(y_t) = [loggas_t logoil_t logI_t] \in \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} + Hx_1 + V_t, \tag{3.17}$$

$$X_t = m_t + e_t, m_t = m_t - 1 + b_t - 1 + h_t, b_t = b_t - 1 - e_t. \tag{3.18}$$

As it seen, except $X_t$ state, it is always composed of two trend elements $m_t$ and one-time element. Trend element is a recursive linear element with random intercept where the variance is trivial, disruption elements $e_t$ and $h_t$ will be constant. The coefficients of trend element and time element form H-matrix. If trend element lacks random nature they can be added as intercepts to the model.

## 4 Results and analysis of findings

### 4.1 Estimation of the demand function for oil products (gasoline, kerosene, gasoil, fuel oil and LPG) along with gas sector energy expenses

The results of estimation of function demand for kerosene, gasoline, gasoil, fuel oil and LPG are shown in Table 1, 2, 3, 4, 5. The values of price elasticity for kerosene, gasoline, gasoil, fuel oil and LPG are -0.14, -0.07, -0.46, -0.10 and -.024 respectively and the amounts of revenue elasticity are 0.48, 0.06, 0.17, 0.48 and 0.01 for kerosene, gasoline, gasoil, fuel oil and LPG, correspondingly. The estimated coefficients indicate real prices for products and real Gross Domestic Product (GDP) in the industrial sector (added value in industrial sector) respectively with relative change in demand for oil products per relative change in their real prices and relative change in demand for oil products per relative change in real GDP in the industrial sector. In fact, they include price and revenue substitution elasticity for oil products with gas sector energy expenses and revenue elasticity of products indicates that kerosene, gasoline, gasoil, fuel oil and LPG are necessary normal products. By comparing logarithm coefficients of real price for oil products and the logarithm of add-value in the industrial sector it is inferred that consumption of all products under current conditions is more sensitive to price than revenue. If $e > 1$, costs for consumers (PXQ) reduce by the rising price of a product and when e=1, costs of consumers do not vary and if $e < 1$, costs increase for consumers. Whereas price elasticity is smaller than the unit for all four products, rising of their prices is led to increase in costs for the producers and rising cost caused the lower growth in the speed of substitution of them with gas. Assuming other conditions are constant, the important factors, which are effective in lower level of price elasticity of a product, include price, GDP, revenue, price of substituted product, growth of world economy, population, expansion of Research and Development fields, market status, climatic conditions, development level of economy, presence of substitutable rival products, exchange rate, expected price, numbers of applicants, previous experiences from variance trend in revenue per capita and Gross Domestic Product (GDP), unexpected shocks in the market, making of economic decisions, formation of investment in oil and gas sector, rate of allocated subsidy by the governments to oil and gas sectors etc. are among others. Thus, the aforesaid factors have caused to reduce sensitivity of producers to variation of their prices. Similarly, there is direct relationship between sale tariff and demand for CNG; namely, by adding one percent increase to sale tariff and freedom of price for kerosene, gasoline, gasoil, fuel oil and LPG, gas demand will be increased 0.46, 0.34, 0.004, 0.17 and 0.11 respectively. In other words, CNG is assumed as an elastic product.

Table 1: Estimation of kerosene demand function with space model and Kalman filter. Source: Researcher Findings

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Value added industry sector | 0.483025 | 0.041653 | 11.59649 | 0.0000 |
| Virtual variable coefficient | 0.465587 | 0.160735 | 2.896604 | 0.0039 |
| | Final State | Root MSE | z-Statistic | Prob. |
| Rotary components of Kalman filter | -0.146263 | 0.076123 | -1.921416 | 0.0554 |

Table 2: Estimation of gasoline demand function. Source: Researcher Findings

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Value-added industry sector | 0.062383 | 0.024218 | 2.575934 | 0.0103 |
| Virtual variable coefficient | 0.347996 | 0.078688 | 4.422469 | 0.0000 |
| | Final State | Root MSE | z-Statistic | Prob. |
| Rotary components of Kalman filter | -0.075534 | 0.028238 | -2.674897 | 0.0092 |

Table 3: Estimation of gas oil demand function. Source: Researcher Findings

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Value-added industry sector | 0.179025 | 0.026678 | 6.710575 | 0.0000 |
| Virtual variable coefficient | 0.004791 | 0.002641 | 1.814028 | 0.0703 |
| | Final State | Root MSE | z-Statistic | Prob. |
| Rotary components of Kalman filter | -0.466731 | 8.91E-07 | -523946.2 | 0.0000 |

Table 4: Estimation of furnace oil demand function. Source: Researcher Findings

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Value-added industry sector | 0.486460 | 0.030706 | 15.84253 | 0.0000 |
| Virtual variable coefficient | 0.177356 | 0.047523 | 3.731967 | 0.0002 |
| | Final State | Root MSE | z-Statistic | Prob. |
| Rotary components of Kalman filter | -0.100792 | 0.034890 | -2.888877 | 0.0040 |

Table 5: Estimation of liquefied gas demand function. Source: Researcher Findings

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Value-added industry sector | 0.017057 | 0.005098 | 3.345780 | 0.0009 |
| Virtual variable coefficient | 0.119064 | 0.007606 | 15.65365 | 0.0000 |
| | Final State | Root MSE | z-Statistic | Prob. |
| Rotary components of Kalman filter | -0.242929 | 0.093662 | -2.593681 | 0.0097 |

Prediction of price elasticity is given for kerosene, gasoline, gasoil, fuel oil and LPG in Table 6. The industrial sector comprises of four groups, including: 1) Industrial, agricultural, and animal-farming units, hotels and resorts; 2) Refineries and pump unit stations owned by Oil Ministry and consuming gas for feeding of petrochemical units and their fuel; 3) Power plants; and 4) The fuel given in CNG substations for transportation use. It is observed that industrial sector includes intensive subsectors; in other words, it comprises all of other sectors such agriculture, power plant, transport and even typically public places. Therefore, it is natural if we witness rising demand for industrial sector by 2025-development outlook. Hence, it is forecast if above-said activities are continued, the amount of gas consumption experiences more than 50% increase in this sector by 2025. The effect of environmental factors has not been identical, especially economic sanctions and fluctuations in exchange rate and rise of prices at public level on producing various field of activities in industrial sector, of course. Rising production costs negatively affected their products in some fields of activities. In contrast, rising exchange rate and increase in price of products in some fields of production activities were led to their positive growth by their positive impact on their profitability and compensation for rising production costs. In this sense, one could refer to positive growth trend in production indicator of various fields of activities such as manufacture of other non-metallic mineral products, production of basic metals, manufacture of machineries and equipment not classified in other place, production of medical instruments, optical tools and precise instruments and types of clock and manufacture of other transportation equipment within 2016 and 2018. Production of other transportation equipment was reduced in 2018 versus 2016 among this series of activities, but despite the problems encountered in industrial sector in 2018, production value parameter at this field of activity enjoyed positive growth rate similar to 4 aforesaid fields as well. Only other mines possessed positive growth rate in industrial group in 2018 while other economic sectors of the country have experienced negative growth because of imposition of economic sanctions, including industrial sector. The maximum negative growth rate was observed in oil and gas extraction sector. As general, it is can be observed it by looking at the findings in Table 6 that the highest price elasticity rate is related to gasoil, fuel oil, kerosene, gasoline and LPG that shows quantity of substitution of gas with oil products by 2025. By looking at growth trend in consumption of oil products over these years until December 2020, it can be seen that rate of growth in consumption is -24.3 for gasoil, gasoline -20.3, kerosene -17.4 and fuel oil -0.14, which are exactly according to results forecast for 2025-development outlook and reduction in consumption of these products is due to substitution of gas demand with them in industrial sector.

According to the results of Table 7, the intrinsic partial elasticity rates have the expected integer negative sign ($S_{ij} < 0$). In other words, the reverse relationship is shown among their prices and demand values. LPG, gasoline, kerosene, gasoil and fuel oil are the substitutes for CNG ($S_{ij} > 0$) and there is greater substitution relationship between fuel oil and gasoil with CNG than the rest. In other words, increase in price of kerosene and gasoil may lead to rising consumption of CNG and whereas substitution elasticity is greater than unit, this may accelerate the aforesaid trend, substitution of LPG, gasoline, gasoil and fuel oil with CNG increases CNG consumption due to intrinsic negative price elasticity and this can be useful in inadvertent increase and also overuse and non-optimal consumption. Similarly, small quantity of partial elasticity ($S_{ij} = 0$) may show there is no great relationship between these two inputs and price variance in one of them will not too effective in demand for another. Based on results of Table 7, gasoline and fuel oil, kerosene and fuel oil and gasoil and fuel oil are not highly related to each other.

Substitution elasticity of oil products includes fuel oil (red chart (EQ01)), gasoil (Green chart (EQ02)), gasoline (Brown chart (EQ03)), kerosene (indigo chart (EQ04)) and LPG (Violet diagram (EQ05)) along with (Blue chart (TC)) are shown in Figure 1. The results of diagram have been indicated as per the results in Kalman filter and the highest substitution elasticity to CNG during period (2006-2019) belongs to gasoil, fuel oil, kerosene, gasoline and LPG respectively so that chart trend for studied variables is also adjusted to growth of consumption of oil products during these years as well.

Table 6: Estimation of liquefied gas demand function. Source: Researcher Findings

| | Kerosene price elasticity | Gasoline price elasticity | Gas oil price elasticity | Furnace oil price elasticity | Liquid gas price elasticity |
|---|---|---|---|---|---|
| 1399Q3 | -0.05921 | -0.05225 | -0.08027 | -0.07572 | -0.04134 |
| 1399Q4 | -0.05923 | -0.05237 | -0.07997 | -0.07592 | -0.04134 |
| 1400Q1 | -0.05926 | -0.05248 | -0.07973 | -0.07611 | -0.04141 |
| 1400Q2 | -0.05928 | -0.05259 | -0.07953 | -0.07628 | -0.0414 |
| 1400Q3 | -0.0593 | -0.05269 | -0.07936 | -0.07644 | -0.04146 |
| 1400Q4 | -0.05932 | -0.0528 | -0.07922 | -0.07658 | -0.04146 |
| 1401Q1 | -0.05934 | -0.05289 | -0.07911 | -0.07671 | -0.04151 |
| 1401Q2 | -0.05935 | -0.05299 | -0.07901 | -0.07684 | -0.04151 |
| 1401Q3 | -0.05937 | -0.05308 | -0.07893 | -0.07695 | -0.04156 |
| 1401Q4 | -0.05938 | -0.05316 | -0.07887 | -0.07705 | -0.04156 |
| 1402Q1 | -0.0594 | -0.05325 | -0.07881 | -0.07714 | -0.0416 |
| 1402Q2 | -0.05941 | -0.05333 | -0.07876 | -0.07723 | -0.0416 |
| 1402Q3 | -0.05942 | -0.05341 | -0.07873 | -0.07731 | -0.04164 |
| 1402Q4 | -0.05944 | -0.05349 | -0.07869 | -0.07738 | -0.04164 |
| 1403Q1 | -0.05945 | -0.05356 | -0.07867 | -0.07744 | -0.04168 |
| 1403Q2 | -0.05946 | -0.05363 | -0.07865 | -0.0775 | -0.04167 |
| 1403Q3 | -0.05947 | -0.0537 | -0.07863 | -0.07756 | -0.04171 |
| 1403Q4 | -0.05948 | -0.05376 | -0.07861 | -0.07761 | -0.0417 |
| 1404Q1 | -0.05949 | -0.05383 | -0.0786 | -0.07766 | -0.04174 |
| 1404Q2 | -0.0595 | -0.05389 | -0.07859 | -0.0777 | -0.04173 |
| 1404Q3 | -0.0595 | -0.05395 | -0.07858 | -0.07774 | -0.04176 |
| 1404Q4 | -0.05951 | -0.05401 | -0.07857 | -0.07778 | -0.04176 |

Table 7: Estimation of substitution tensions between different energy carriers. Source: Researcher Findings

| | | Fuel oil | Fuel oil | Gas oil | Kerosene | Petrol | liquid gas |
|---|---|---|---|---|---|---|---|
| liquid gas | GAS | -1.68 | 0.89 | 0.67 | 1.12 | 0.59 | 0.97 |
| Petrol | BEN | - | -0.79 | 0.71 | 0.47 | 0.07 | 1.16 |
| Kerosene | KER | - | - | -2.36 | 1.19 | 0.06 | 1.48 |
| Gas oil | GOI | - | - | - | -3.87 | 0.04 | 1.52 |
| Fuel oil | FOI | - | - | - | - | -2.97 | 1.55 |
| Fuel oil | LPG | - | - | - | - | - | -1.47 |

## 5 Discussion and conclusion

It was discussed about dynamism of substitution elasticity levels between fossil energy carriers in Iran in this study and policy related guidelines were presented for gas consumption in industrial sector for 2025-development outlook. Although the outlook document for Iranian oil and gas industry in 2025 seems as a comprehensive plan at first glance, the status quo in national oil and gas industry has not been addressed and consequently the country is distant from the listed objectives in this document. Industry is the third energy-intensive sector in the country and at the same time it has been exposed with high growth in energy consumption in recent years. Some of major reasons for relative economic improvement in industrial sector during recent years are the emphasized solutions in the 6th National Economic Development Plan to support from production units e.g. mechanisms for administered funds, financing for execution of emergent employment plan, granting foreign exchange facilities, use of foreign finance facilities, utilization from subsidy of facility interests in the field of optimization in using fuel and electrical energy. The standards and regulations have been codified for reduced fuel consumption in this sector at favorable speed in recent years and it has been also more effective than in other sectors. Nevertheless, due to imperfect observance of consumption standards

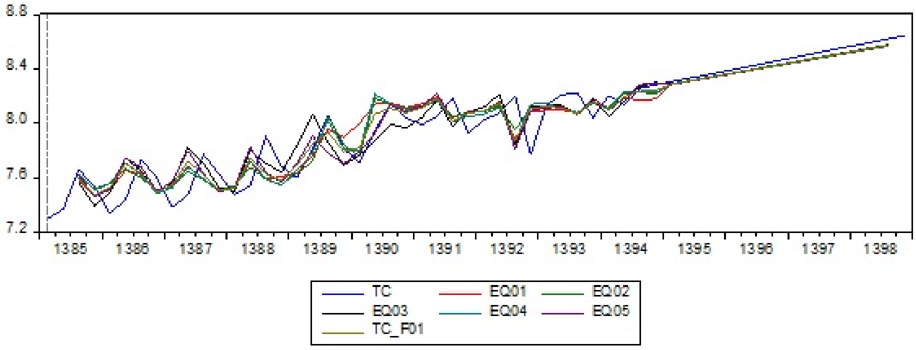


Figure 1: Graphic trend of replacement of petroleum products with natural gas. Source: Researcher Findings

in some of industries at this sector and very low price of energy and shortage of the necessary rewarding and punitive arms, energy consumption in various industries is still very distant from world models. The noticeable point, which should be mentioned in this sector, is the status of refineries, petrochemical industries and national power plants where similar analyses in these units may also show requisite for codification and quick implementation of criteria and standards in accordance with world norms for them. By taking policy for substitution of oil products with CNG at this period, production of crude oil has been developed at annual rate 2.6% and production of CNG increased at rate 12.1%. Due to execution of above-said policy, portion of petroleum has been reduced from 89.5% to 42.5% in supply of initial energy and in contrast, portion of CNG has been increased from 8.5% to 63.5%. The consumption of four sectors, including household and trade, power plant, industry and refinery as the most important CNG intensive sectors in the country, experienced annual mean growth rates of 10.5, 8, 10 and 13 within the given period. With respect to gas substitution policy in aforesaid sectors and the consequence of rising growth in gas consumption compared to growth rate in other energy carriers at the given sectors, gas portion has frequently increased in these sectors and on the other hand transportation sector is also added to intensive consumers in this sector with respect to the policies relating to reduction of gasoline consumption and decrease in air pollution. Rising CNG production at annual average rate of 12% increased gas production from 105.9 billion cubic meters in 2005 to 300 billion cubic meters in 2020. Thus, if the combined capacity of production in National Iranian Gas Company (NIGS) proceeds according the plan, the current product capacity will increase from about 300 billion cubic meters to 396 billion cubic meters at annual average growth rate 8% by 2025-plan outlook (of course, substitution of gas with oil products grows at relatively low speed). With respect to these topics and the given results in fourth section, some suggestions are proposed in this regard: Whereas industrial sector plays pivotal role in economic development of any country, rise of price and omission of paid subsidies for energy carriers should be done within several steps thereby the industries of the country to be able to perform the needed reforms and adjustments in technological sector. The conducted investigations may indicate that if subsidies are omitted gradually for energy carriers in industrial sector, it causes this sector to be less exposed to lesser reduction in giving of their services because other sectors find adequate opportunity to improve their production techniques and for optimization of using fuels and substitution. Likewise, some efforts could solve the problem in substitution of gas with oil products and reduction of consumption in this sector such as exiting worn machineries and equipment of use, enforcement of manufacturers of industrial machineries and equipment at this industries to produce cost-effective machineries and equipment and according to world standards in terms of fuel consumption, upgrading of competition level in manufacturers of industrial machineries by liberalization for importation of these machineries in a timetable schedule and gradual decrease in rate of custom tariffs for importation of these machineries and pricing for electricity, oil and gas and industrial machineries based on market mechanism. Presence of some external factors and unpredicted plans in 2025-Outlook Plan, including economic sanctions and prohibited importation of equipment in industrial sector have led to reducing speed in substitution of oil products with gas. Thus, sudden rise in price of energy carriers to the level of boundary prices (sudden omission of subsidy for energy carriers) may increase prices of various products and create inflation in economy and due to change in relative prices, it causes reduced production in some economic sectors e.g. industry, transportation, and some of servicing sectors and extraction industries, water and related services etc. It seems these sectors, which are more energy-intensive than other sectors, will not have adequate time to improve method of their production and coping with the negative consequences for rising prices following to sudden rise in prices of energy carriers to the level of boundary prices. Thus, by selection of longer time period for increase in prices and omission of paid subsidy for energy carriers, the necessary time and sources will be provided for exposure to the negative consequences of rising prices. Similarly, the government can be effective in implementation of non-subsidized supportive policies in some national sectors e.g. industrial sector that is more exposed to vulnerability in achievement of plan to increase price of energy carriers and omission of paid subsidies to them by using more appropriately from the savings created by reducing subsidies. The above-said objective may not be realized generally without comprehensive energy management by taking corrective approach toward consumption model, especially in supply and demand sector and as a result it requires for the aforesaid approach to enjoy necessary mechanisms for spread and development in all fields. With respect to the aforementioned items and contents, execution and codification of national comprehensive energy plan is proposed as a national requisite by aiming at energy management and especially energy intensive improvement by rising efficiency and productivity of energy using modern technologies, which are assumed as important factors in realization of 20 year national energy outlook plan.

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