# An Approach on Manufacturers' Fuel Bills in Iran's Electricity Industry Competition

**Abstract**

Power plants have to pay costs according to the fuel used for energy production according to the current laws related to Iran's electricity industry. On the other hand, by default, gas is the fuel needed by power plants, whereas diesel and mazut consumption is unavoidable. In this regard, to the transparency of issuing fuel bills by the power plant and its effects, the laws regulated by the Iranian Electricity Network Management Company have been simulated and implemented. The values obtained by law applied for issuing bills of power plants participating in the Iranian electricity industry were presented during 2013-2020.

**Keywords:** Electricity industry, Bill, Fuel consumption

## Introduction

A considerable evolution has emerged in managing and operating the electricity network around the world compared to the traditional structure through restructuring and creating the concept of the electricity industry. Reduction of government tenure, creating an environment of competition and preventing monopoly, compliance with international laws and regional conditions, promotion of public space for foreign investment, encouraging the national economy to balance payments, technology transfer and job creation, encouraging the development of technology in different sectors, the opportunity to provide services for customers with different needs, and ensuring the long-term benefits are among the restructuring motivations [1-2]. Also, in a defined framework, the electricity industry goes through four stages separation, revision of regulations, creation of a competitive environment, and privatization. In this situation, the four stages of construction, ownership, exploitation, and trade are changed from an exclusive state. Reducing costs, improving economic productivity, transparency of costs, and encouragement to increase efficiency are expected from the electricity industry. It is necessary to use of clear calculation method for related bills in the electricity industry, considering that the power plants are the electricity subscriber, producers, and consumers [3-4].

By default, gas is the fuel needed for power plants, whereas, it is possible that in situations such as fuel shortages and limitations, especially in the cold season for electricity generation, alternative fuels such as diesel and mazut also play an essential role in the fuel supply chain of power plants, which will naturally involve additional costs for the power plant. In general, in the production arrangement program in Iran's electricity industry, the priority belongs to the gas-fueled power plants so that the environmental restrictions are more appropriately observed [5].

The bills for the purchaser (power distribution companies and regional power companies) and sellers (power plants) are issued in the middle of each month. For the sellers, this invoice has two main parts, including an electricity sales invoice for the power plant and a fuel consumption invoice. Since the fuel price (the basic price of gas consumption for determining the maximum price of energy) is needed for determining the maximum price of energy, the imposed prices more than this rate should be checked by the management of the electricity industry. Considering the issued bill for the power plants by the national gas company of Iran, the difference between the rate recorded in the bill and the base rate of gas fuel is paid to the power plants to determine the market price ceiling under the title of fuel cost compensation and fuel cost difference compensation. Also, if the efficiency of the power plant is higher than the average efficiency of the thermal units due to saving fuel consumption, an item called an efficiency bonus is paid to the power plant to create motivation to increase the efficiency of the power plant units. The cases will be explained in detail in the following [6-7].

In this study, fuel consumption in power plants of the country is presented first during 2013-2020 (the latest information of definite bills by the country's electricity industry in 2020). The implementation method and the equations related to different quantities of fuel in the bills of power plants are stated in the following. Finally, the cost of fuel consumed by power plants has been mentioned for eight years.

## Fuel consumption in power plants

The fuel used in Iran's power plants is gas, mazut, and diesel fuel which gas fuel has the largest share. In terms of power generation technology, gas power plants do not have the ability to burn mazut, and they work with gas or diesel.

In combined cycle power plants, the most fuel is consumed by gas units and the little consumed by steam units. Steam units do not have the limitations of gas units and can also use mazut fuel. Due to the lack of gas fuel in recent years, the consumption of liquid fuel (mazut and diesel) has grown significantly, which is associated with destructive technical and economic effects and adverse environmental consequences. Every year in the cold season, the power plants encounter the problem of fuel supply and restriction due to the increase in gas consumption and the priority of supplying gas to the households. The number of fuel restriction hours decreased from 2016 to 2018. Whoever, this trend changed in 2018 and the number of hours of fuel restriction increased significantly. As a result, due to the gas fuel supply crisis of power plants, the consumption of liquid fuel has increased during these years. The consumption of mazut was decreasing during 2013-2018, which changed over the following years. In the case of diesel, the decreased trend increased in 2017, and gas consumption has changed in the opposite direction of liquid fuel [8-9].

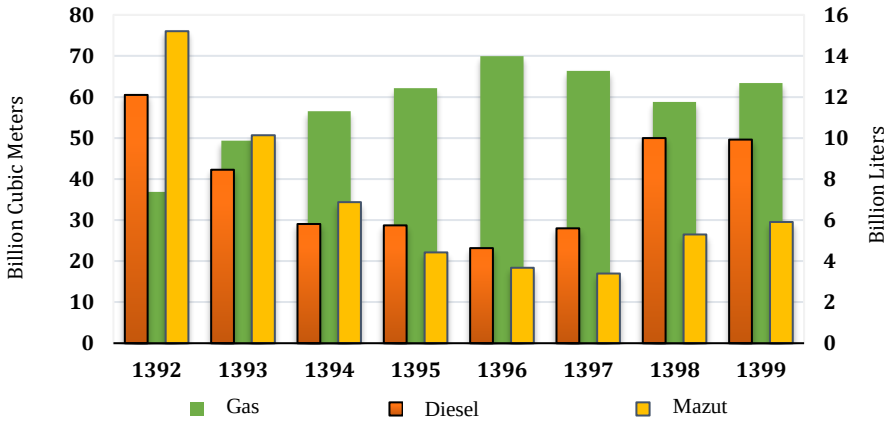


**Figure 1) F**uel consumed by power plants over eight years

Another noteworthy point in the fuel consumption of power plants is the amount of liquid fuel consumption, which trend can be seen in figure 2. This graph shows the volume of liquid fuel consumption by power plants over 2013-2020. As can be seen, in 2017, the consumption of liquid fuel started growing, whereas it almost doubled in 2020.

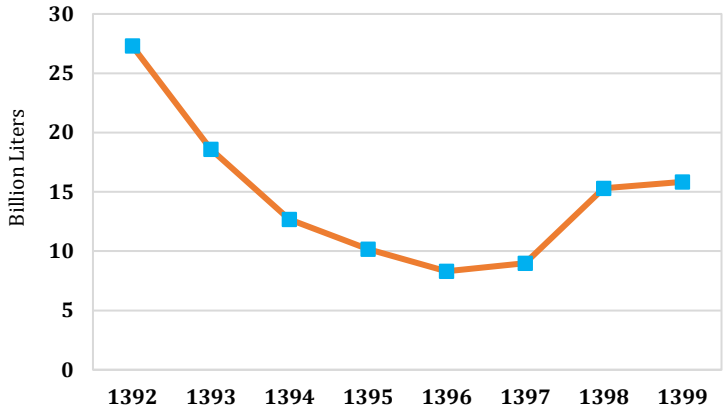


**Figure 2)** Total liquid fuel consumption of power plants over eight years

## Calculation of fuel bills for power plants

Power plant gas fuel rate (FSP_Gas) and free rate of natural gas consumption (FFP_Gas), are the rates determined by the legal authorities for the natural gas fuel consumed by the power plant, which is required from the specialized thermal power generation company. Gas fuel rate is based on the market price ceiling ($\pi\_Gas\_Market$) and is the determined rate based on the ceiling rate of energy sales in the electricity industry (currently equal to 642,000 Riyal/kWh).

**Table 1)** Fuel price

| In terms of Rials per cubic meter/Rials per liter | | | | |
|---|---|---|---|---|
| **Year** | **Gas price** | **Diese price** | **Mazut price** | **Gas fuel base rate to determine the market ceiling price** |
| **2013-2015** | 800 | 2/100 | 1/300 | 700 |
| **2016** | 607 | 607 | 607 | 700 in the first nine months and then 607 |
| **2017-2020** | 50 | 50 | 50 | 607 |
| **2021** | 100 | 100 | 100 | 100 |

Currently, despite the difference between the price of power plant gas and the price of gas fuel based on the market price ceiling, the industry manager will pay the cost difference caused by this price difference under the title of gas fuel cost compensation to each power plant. Also the industry

manager pays an amount called the fuel difference to the power plants due to the difference in the delivered gas perice and the power plant gas price, the difference in the quality of delivered liquid fuel and gas across the country, and also delivery of liquid fuel instead of gas fuel in some periods of time. The owner of the power plant pays an amount in cash based on the fuel price of power plant gas to Iran National Gas Company (National Oil Products Distribution and Refining Company) for every cubic meter (liter) of gas (petroleum products). Since power plant efficiency plays a significant role in reducing fuel industry and this saves fossil fuel consumption and reduces its polluting and destructive effects, the industry manager measures the efficiency of each power plant and compares it with the average efficiency of thermal power plants to apply the efficiency bonus (penalty). The net efficiency of each power is required from the specialized company of thermal power generation or it is calculated using the volume of fuel consumed. In the case of those power plants that supply all their generated electricity through the grid, their net efficiency is assumed to be 20% by default if they do not inform the power industry manager of the efficiency confirmed by the expert. Also, the onvection of the consumed gas and liquid fuel, must be approved by the expert selected by the Electricity Industry Regulation Board. The amount of fuel consumed for each power plant during the fuel billing period is inquired from the specialized company of thermal power generation.
Efficiency and volume of fuel consumed by the power plant is calculated by dividing the amount of energy produced by each power plant in a month by the amount of fuel consumed and the value of the types of fuel consumed (Equiption 1).

$$\eta_{pp} = \frac{3600 \times 1000 \times \sum_{d=1}^{N\_day} \sum_{h=1}^{24} E\_TG_h}{4.1868 \times \sum_{d=1}^{N\_day} \sum_{h=1}^{24} \begin{pmatrix} Fuel\_Gas_{pp} \times FHV\_Gas + \\ Fuel\_GOil_{pp} \times FHV\_GOil_{pp} + \\ Fuel\_M_{pp} \times FHV\_M_{pp} \end{pmatrix}} \quad (1$$

Fuel cost compensation is calculated for the three parts of gas, diesel, and mazut fuel cost compensation as described in equation 2.

$$Cos\_Fuel\_Comp_{pp} = Comp\_Gas_{pp} + Comp\_GOil_{pp} + Comp\_M_{pp}$$
$$\pi\_Fuel\_Comp_{pp} = (FSP\_Gas - \pi\_Gas\_Market)$$
$$Comp\_Gas_{pp} = Fuel\_Gas_{pp} \times \pi\_Fuel\_Comp_{pp} \quad ((2$$
$$Comp\_GOil_{pp} = Fuel\_GOil_{pp} \times \pi\_Fuel\_Comp_{pp}$$
$$Comp\_M_{pp} = Fuel\_M_{pp} \times \pi\_Fuel\_Comp_{pp}$$

The payment difference for fuel is calculated for gas, diesel and mazut fuel as described in equation 3.

$$\Delta Payment\_Fuel_{pp} = \Delta Payment\_Gas_{pp} + \Delta Payment\_GOil_{pp} + \Delta Payment\_M_{pp}$$

$$\Delta Payment\_Gas_{pp} = Fuel\_Gas_{pp} \times \left[ \left( \pi\_Gas_{pp} - FSP_{Gas} + \pi\_Gas\_Market \times \left(1 - \frac{FHV\_Gas_{pp}}{FHV\_Gas_N}\right)\right)\right]$$

$$\Delta Payment\_GOil_{pp} = Fuel\_GOil_{pp} \times \left[ \left( \pi\_GOil_{pp} - FSP_{Gas} + \pi\_Gas\_Market \times \left(1 - \frac{FHV\_GOil_{pp}}{FHV\_Gas_N}\right)\right)\right] \quad (3$$

$$\Delta Payment\_M_{pp} = Fuel\_M_{pp} \times \left[ \left( \pi\_M_{pp} - FSP_{Gas} + \pi\_Gas\_Market \times \left(1 - \frac{FHV\_M_{pp}}{FHV\_Gas_N}\right)\right)\right]$$

The heat of combustion of gas fuel in the grid, which is calculated by equation 4:

$$FHV\_Gas_N = \frac{\sum_{pp=1}^{Npp}(Fuel\_Gas_{pp} \times FHV\_Gas_{pp})}{\sum_{pp=1}^{Npp} Fuel\_Gas_{pp}} \quad (4$$

Efficiency penalty and bonus

Efficiency penalty and the bonus is calculated using the following equation:

$$\Delta Payment\_Efficiency_{pp} = \left(\sum_{ppg=1}^{Nppg_{pp}} \sum_{d=1}^{N_{day}} \sum_{h=1}^{24} E\_TGU_{pp,ppg,h}\right) \times \frac{3600 \times 1000}{4.1868 \times FHV\_Gas_N} \times \left(\frac{1}{\eta_{Ave}} - \frac{1}{\eta_{pp}}\right) \times (FFP\_Gas - FSP\_Gas) \quad (5$$

$$\forall pp \in \{1,2,3,\dots,Npp\}$$

The average efficiency of grid thermal units, that have signed an electricity purchase contract with the network management, is calculated using equation 6:

$$\eta_{Ave} = \frac{3600 \times 1000 \times \sum_{pp=1}^{Npp} \sum_{d=1}^{N\_day} \sum_{h=1}^{24} E\_TG_{pp,h}}{4.1868 \times \sum_{pp=1}^{Npp} \left( \begin{matrix} Fuel\_Gas_{pp} \times FHV\_Gas_{pp} + \\ Fuel\_GOil_{pp} \times FHV\_GOil_{pp} + \\ Fuel\_M_{pp} \times FHV\_M_{pp} \end{matrix} \right)} \quad (6$$

**Fuel cost**

The actual fuel cost of the power plant is calculated according to the bill issued from equation 7:

$$Cos\_Fuel_{pp} = \left(Fuel\_Gas_{pp} \times \pi\_Gas_{pp}\right) + \left(Fuel\_GOil_{pp} \times \pi\_GOil_{pp}\right) + \left(Fuel\_M_{pp} \times \pi\_M_{pp}\right) \quad (7$$

The cost of gas fuel is obtained from the heat of combustion of each fuel used in the power plant and its price and it is the amount that the power plant pays for its fuel consumption. Also, the total fuel cost is the actual and final value of the fuel consumed which is obtained from the sum of the product of the volume of fuel consumed and the value of fuel or it is obtained from the total cost of gas fuel with the cost of fuel difference and gas fuel cost compensation.

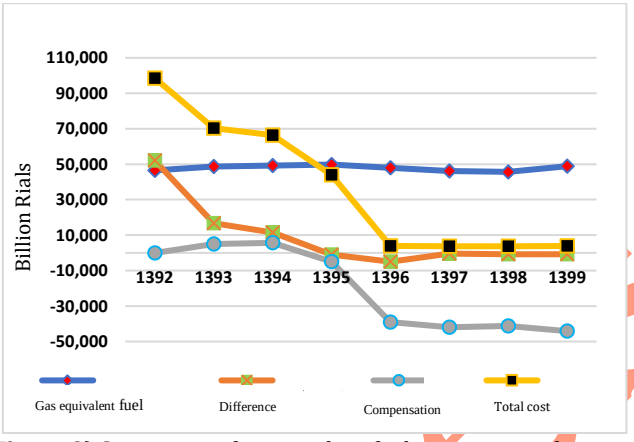


**Figure 3)** Separation of power plant fuel costs over eight years

Considering the decrease in the fuel rate of the power plant, it can be seen that the total cost of fuel is greatly reduced and inexpensive fuel is provided to the power plants. A considerable difference was observed between the average purchase rate of electricity from thermal power plants and the average rate of fuel to heat energy produced during the study period, so that the cost of fuel is almost insignificant and will definitely leave alarming consequences.

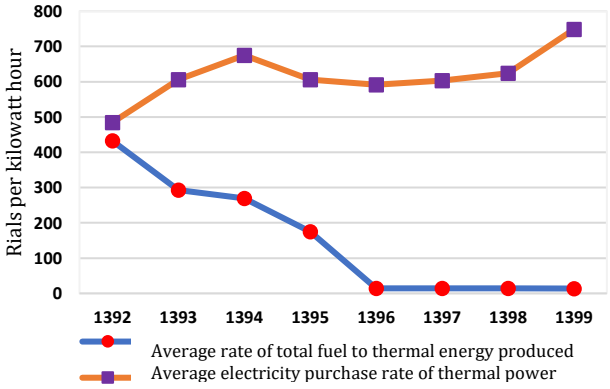


**Figure 4)** Average fuel rates and electricity purchase of thermal power plants over 8 years

The amount of energy produced by thermal power plants during the last few years has been shown in Figure 5 which has been increasing in all years except 2018. Due to the adequate rainfall, the production of hydroelectric power grew significantly in 2018.

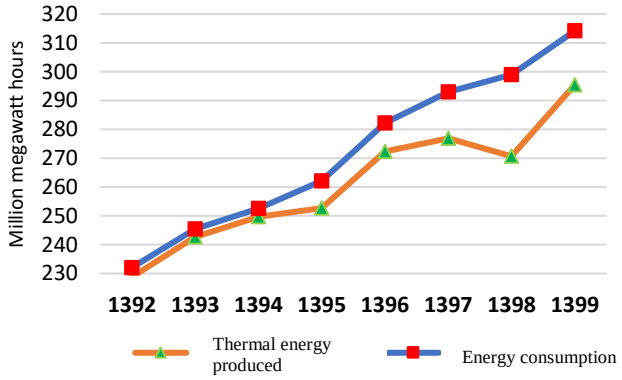


**Figure 5)** Energy consumption and thermal energy produced during eight years

## Conclusion

This study aimed to calculate the fuel bills of participating power plants in Iran's electricity industry. In this context, some items were explained including of compensation for fuel cost, compensation for the difference and penalty/bonus of efficiency. Considering different rates of fuel, each of the quantities may be equal to zero or even negative. Since in planning the production of power plants, power plants with higher efficiency and gas fuel consumption should be prioritized, determining different rates may cause non-optimality in fuel allocation. Also, the irrational determination of the indicated rates can have a significant impact on the efficiency or ineffectiveness of fuel bill calculations.

| | |
|---|---|
| $Cos\_Fuel\_Comp$ | Fuel cost compensation, Rial |
| $Comp\_Gas$ | Gas fuel compensation, Rial |
| $Comp\_GOil$ | Diesel fuel compensation, Rial |
| $Comp\_M$ | Mazut fuel compensation, Rial |
| $E\_TG$ | Rate of energy production, MWh |
| $Fuel$ | Fuel volume (gas, mazut and diesel), m3 or lit |
| $Fuel\_Gas$ | Heat of combustion of gas fuel, kCal/$m^3$ |
| $Fuel\_GOil$ | Heat of combustion of diesel fuel, kCal/$m^3$ |
| $Fuel\_M$ | Heat of combustion of mazut, kCal/lit |
| $FHV\_Gas$ | Gas fuel volume, m3 |
| $FHV\_GOil$ | Diesel fuel volume, lit |
| $FHV\_M$ | Mazut fuel volume, lit |
| $FHV\_Gas_N$ | Heat of combustion of gas fuel, kCal/m^3 |
| $FFP\_Gas$ | Free rate of gas fuel of the power plant, Rial/m3 |
| $FSP\_Gas$ | Power plant gas fuel rate, Rial/m3 |
| $\pi\_Fuel\_Comp$ | Fuel cost compensation rate, Rial/m3 |
| $\pi\_Gas\_Market$ | Gas fuel rate based on market price ceiling, Rial/m3 |
| $\pi\_Fuel\_Comp$ | Fuel cost compensation rate, Rial/m3 |
| $\Delta Payment\_Fuel$ | Cost difference of fuel, Rial |
| $\Delta Payment\_Gas$ | Cost difference of gas fuel, Rial |
| $\Delta Payment\_GOil$ | Cost difference of diesel fuel, Rial |
| $\Delta Payment\_M$ | Cost difference of mazut, Rial |
| $\pi\_Gas$ | Gas rate delivered to the power plant, Rial/m3 |
| $\pi\_GOil$ | Price of diesel delivered to the power plant, Rial/lit |
| $\pi\_M$ | Rate of mazut delivered to the power plant, Rial/lit |
| $\Delta Payment\_Efficiency$ | Efficiency penalty and bonus, Rial |
| $\pi\_Gas$ | Rate included in the gas bill of the power plant, Rial/$m^3$ |
| $\pi\_GOil$ | Rate included in the diesel fuel bill of the power plant, Rial/lit |
| $\pi\_M$ | Rate included in the power plant diesel fuel bill, Rial/lit |
| $\eta$ | Efficiency |
| $pp$ | Power plant counter |
| $N\_day$ | Number of days in an year |
| $d$ | Year days counter |
| $h$ | Hour counter |

| | |
|---|---|
| $Npp$ | Number of thermal power plants in the network |
| $Nppg$ | Number of power plant units |
| $Ave$ | Average |
| $N$ | Network |