Effects of Gas Subsidy on the Behavior of Power Stations in Iran: A new policy for reducing energy intensity in electricity powerhouses

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Abstract
Presently in Iran, gas-driven power stations and combined-cycle power stations compete as they share a common budget allocated by the government for their establishment. With the government offering gas at subsidized rates, the cost price of electricity production at gas-driven power stations is comparatively lower, thereby enhancing their attractiveness for the investor. Therefore, despite their decreased efficiency, the establishment of such power stations is on the increase which in turn imposes additional costs for the government. On the other hand, it would be in the best interest of the government to help increase investment in combined cycle power stations which are far superior in terms of efficiency, and which, in the long run, would be profitable. In this paper we present a model and suggest policies for the government through which a decrease in energy intensity can be achieved without incurring additional costs for the government. We suggest practical ways to optimize existing methods of power production by diverting subsidies offered by the government.

Introduction

Main Variables

- *Power Station*: By power station we mean the power station producing electrical energy divided into two sets of cycles: combined cycle power stations and gas driven power stations. Other power stations are not of concern in this paper.
- *Unit of measurement*: Numbers (to simplify the modeling, every power station is assumed to produce a definite amount of electrical energy, for instance, 2000 megawatts and this amount is considered as one power station.
- *Current production*: The sum total of gas-driven and combined-cycle power stations, practically indicating the number of existing power stations and based on the above

assumption, this number along with a specific coefficient can express the rate of production.

- *Investment*: The fixed amount of annual investment required for the installation of a new power station or optimization of existing power plants is considered, which for the purpose of our model is taken as 2500 units. Investment may be for the installation of gas-driven or combined-cycle power stations. Similarly, investment for optimization includes both conversion of gas-driven power stations to combined-cycle power stations, optimization of an existing power station without any essential changes in the method or storage/savings.
- *Savings of investment:* The amount of annual investment not utilized per year is saved in this stock variable. These savings can be used to invest in new forms of energy, the discussion of which is beyond the scope of this paper.
- *Cost price of electricity:* The cost price of one unit of electricity at every power station (gas or combined cycle) which is related to the cost of gas consumed, efficiency of the power station, cost of installing the power station, and expected viability of the power station.
- *Attractiveness of the power station:* The attractiveness of the installation of a power station, combined-cycle or gas-driven, is determined by taking into account the amount of profit obtained from the sale of electricity. The lower the cost price of producing electricity, the greater the profit obtained and the greater the attractiveness of that kind of power station for the investor.
- *Opportunistic cost of gas consumption:* In this model, the government is the producer of gas and the gas extracted and prepared for utilization by the government may be used by power stations, sold domestically, or exported. The most profitable use of gas in Iran is its export. The difference in cost of gas exported and gas sold to electric power station is in effect the cost which is created indirectly for the government and is termed opportunistic cost of gas consumption in power stations.
- *Subsidy:* Here we assume that the government sells gas to electric power stations for a price lower than that of export gas, and also makes electricity available to the consumer free of charge. The sum total of these two costs is termed subsidy.

Dynamic hypothesis and cause effect model

At any given time in any country, a certain amount of electricity is required and in some countries like Iran, the amount exceeds the amount currently produced. The amount of electricity required is termed desirable production. The discrepancy between current production and desirable production leads to increased investment which in turn results in a reduction of this discrepancy, followed by a decrease in investment for the installation of new power stations. This decrease in investment has delayed effects which become evident in the number of gas-driven power stations: the rate of their increase decreases and, as a consequence, current productions will decrease. This behavior which is a purposive loop, exists as a similar process in combined cycle power stations too. Both loops are illustrated in the figure below.

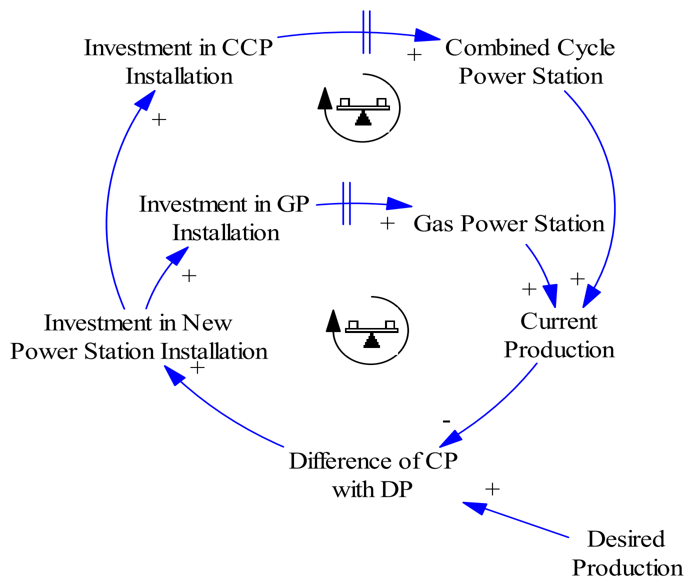

Figure 1: Balancing loops for investment in new power stations.

As shown here gas-driven power stations and combined-cycle power stations compete with each other as they share the common budget, which is referred to as investment for installation. The competitive advantage here is the amount of profit determined from the cost price of electricity production and the selling price of electricity.

Since in Iran, as in many other countries, the price of electricity is determined by the government so as to combat the natural monopoly that exits is this sector the price of electricity can be considered an extraneous variable and the cost price of electricity production by gas and combined cycle power stations directly affects the extent of installation of that type of power station. The lower the cost prices of electricity production at power stations, the greater the investments for the establishment of such power stations.

However, as mentioned in the section pertaining to the description of the major variables, the cost price of electricity production is obtained from the initial investment for the establishment of the power stations, expected life of the power station and efficiency of production which determines the amount of gas consumption. Of these three factors, initial investment of gas-driven and combined-cycle power stations is clear for this reason, in order to reduce the cost price of electricity production, practically it is the expected viability of the power station as well as the efficiency of production that contribute in this dynamic model. In order for power stations, whether gas or combined cycle, to maximize profitability they should produce electricity with the least possible cost price. Therefore, every power station aims at increasing its viability and its production efficiency. This optimization becomes feasible only when the costs justify time for optimization. This process occurs with both gas-driven and combined cycle power stations and creates two purposive loops for each. In the next figure, the two loops relevant to a gas-driven power station can be seen.

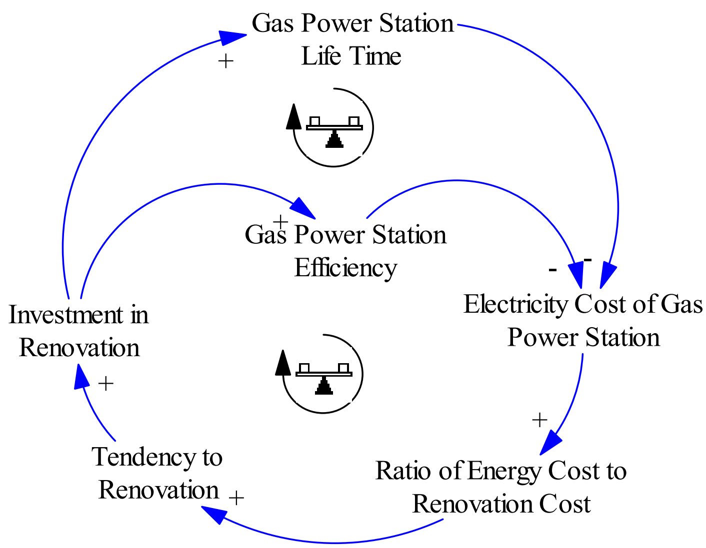

Figure 2: Balancing loops for investment on renovation.

But gas-driven and combined cycle power stations themselves have limitations in expected viability and efficiency which determine a ceiling for their viability and efficiency.

Regarding the efficiency of gas-driven power stations, however, by virtue of the possibility of their conversion to combined-cycle power stations with greater efficiency, this ceiling can be raised. The conversion is accomplished when the process can be justified economically.

We continue with an elaboration of the flow-savings model, and having explained the variables in the model, we will proceed to reveal the problem of energy intensity and its effects in Iran and conclude with suggested policies for reducing the energy intensity in this area.

Flow model

As demonstrated earlier, there are several kinds of loops in this model the cause and effect model of which was illustrated before. Here, the flow model of these loops with several more variables will be shown.

In figure 1 and 4 the first kind of loop is shown. As can be seen, in this model the delay in the installation of power stations is delay of the first degree, which is different in gas-driven and combined cycle power stations. One stock variable termed investment savings is shown in figure 4. Since the amount of annual investment is considered to be fixed, in any given year the input investment/capital may not all be utilized. The amount saved can be invested to produce power stations with recyclable fuel.

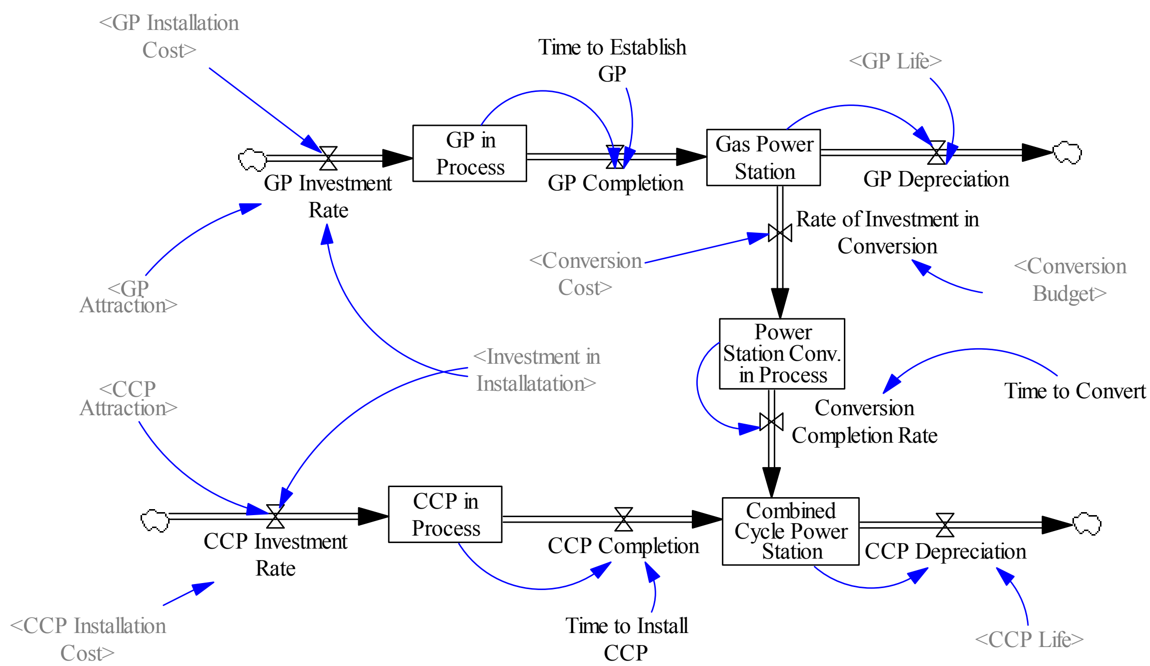

Figure 3: Flow Model: Life of power stations.

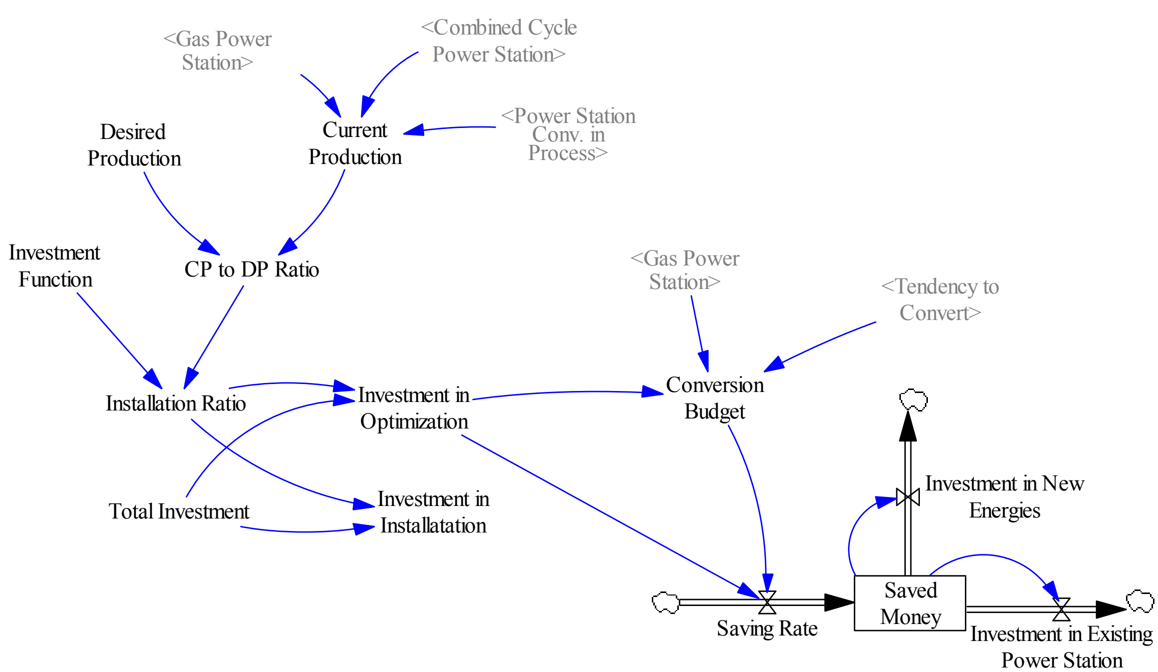

Figure 4: Flow Model: How to invest for power stations.

Another process possible is the conversion of gas-driven power stations to combined-cycle ones. This conversion can be accomplished if justified economically. Figure 5 of the model represents this issue.

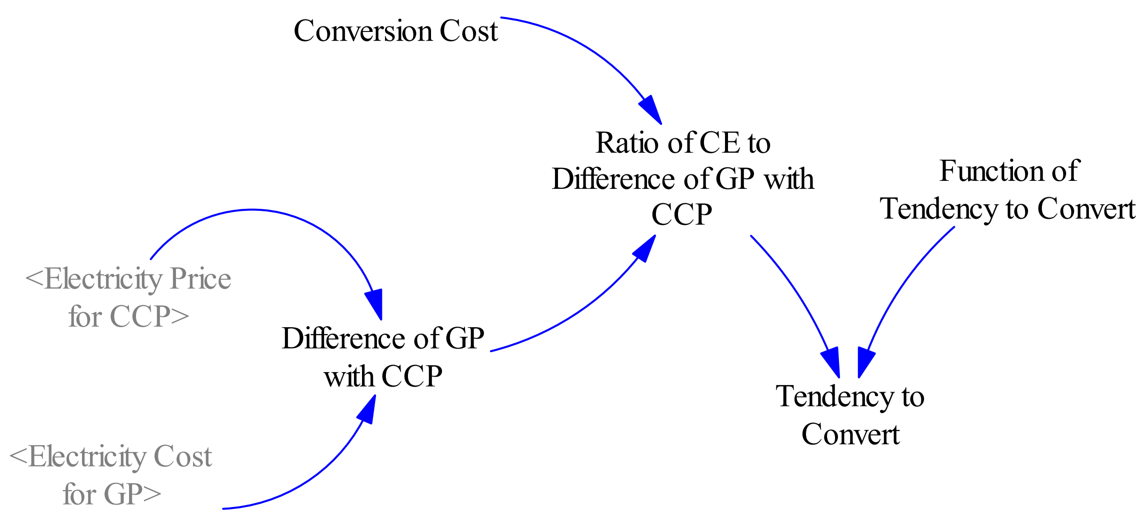

Figure 5: Tendency to convert gas-driven stations to combined-cycle stations.

In fact it is the ratio between amount of savings in costs and conversion costs that push power stations toward conversion. Although this power can enter the model as an external factor, in order to see the dynamics better, external pressures are excluded from consideration.

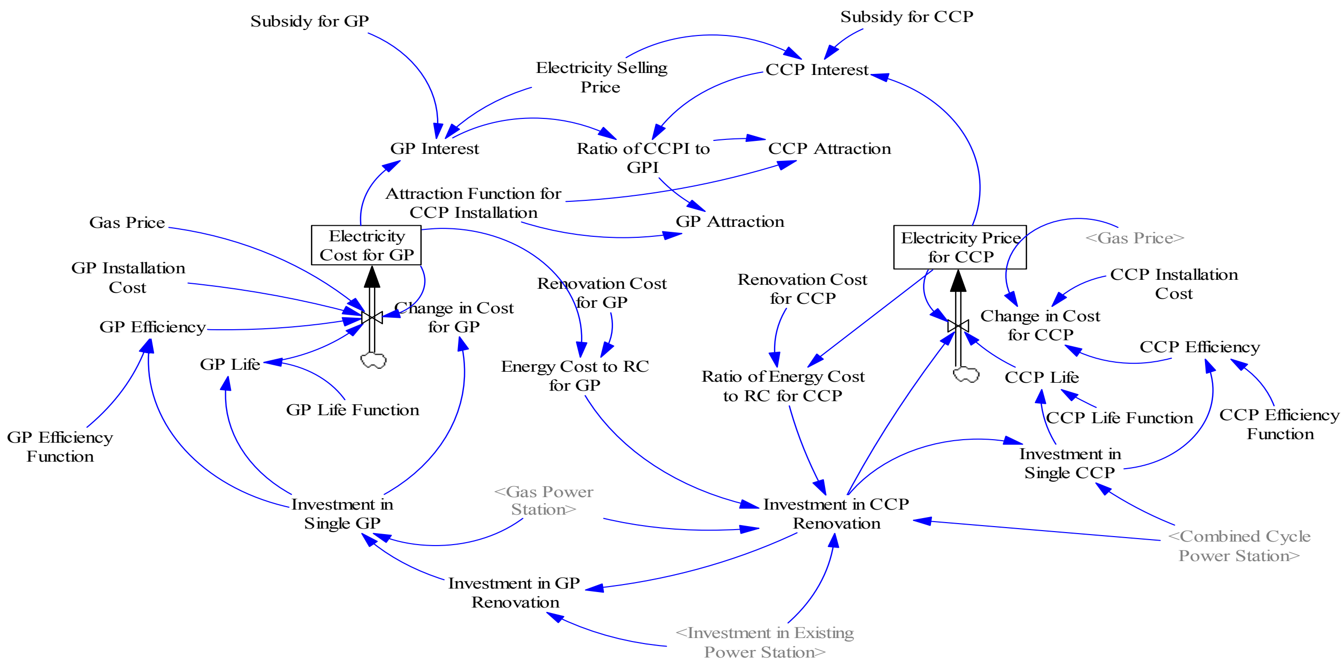

Figure 6: Deciding on how much to invest in each kind of power stations.

In figure 6, two loops of the second kind are illustrated for both combined-cycle and gas-driven power stations. These loops affect the cost price of electricity production. Moreover, the attractiveness for investment in combined-cycle and gas-driven power stations , based on the amount of profit obtained by calculating the difference between selling price and cost price is also shown in the figure.
The last figure (figure 7) is the exponential model for monitoring the situation. Since in such a model it is assumed that the government pays a subsidy to households for electricity, the costs for the government, the subsidy plus the opportunistic cost of exporting gas, is monitored as an important variable in this figure. Another important variable is energy intensity in the industrial sector.

Continuing with the section on the behavioral analysis of the model, it will be shown that through formulating specific policies for the government, energy intensity can be decreased with no increase in costs and if anything, with a decrease in costs. In fact, the main purpose of the present paper is the formulation of these policies.

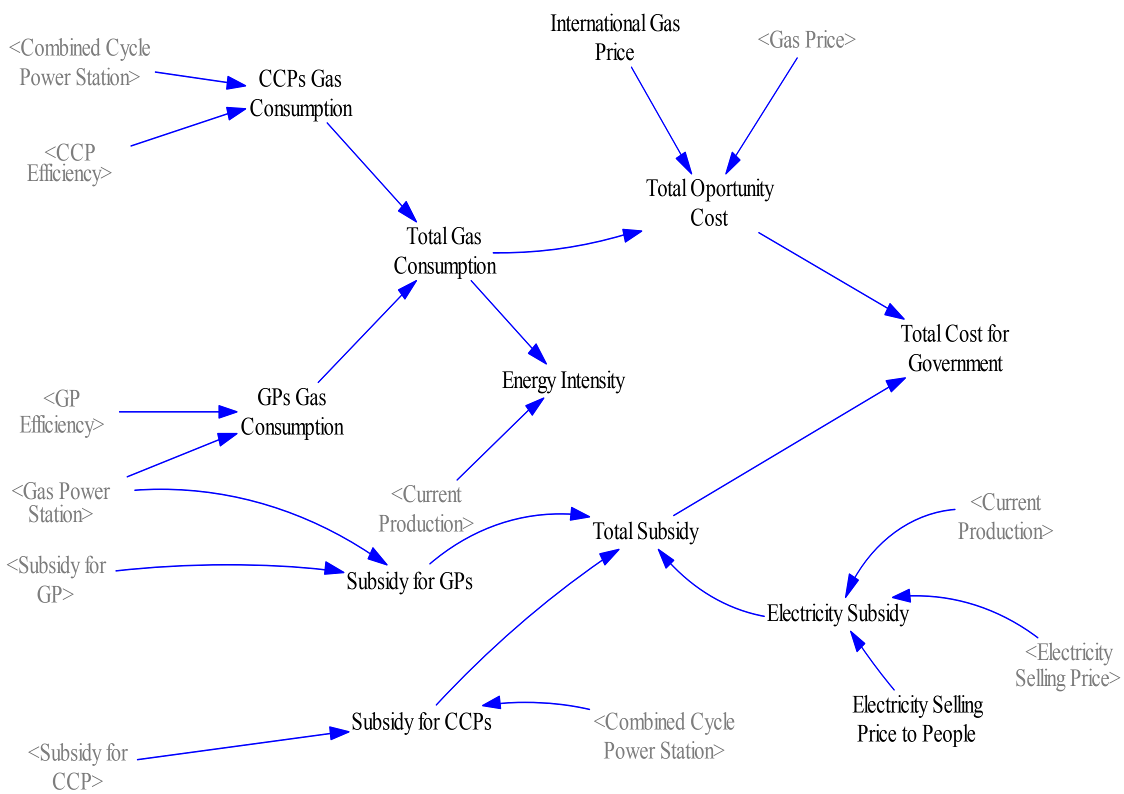

Figure 7: Monitoring the situation for amount of subsidy government pays.

Behavioral analysis

As indicated earlier, the cost price is an important variable in this model in which other variables are influential. The cost of gas and expenses associated with installation are extraneous variables and the efficiency and viability are internal which can be influenced by system dynamics in a loop. But all these variables are not equally influential. When the cost of gas is very cheap, (as is the case in Iran today), it is the expenses associated with installation that determines the cost price. In this situation, the efficiency of the power station is not a determining factor for installation, and it is the expenses associated with installation that makes a particular type of power station attractive. In such a situation, the opportunistic cost to use gas is high but is overlooked. That is, the crucial factor determining investment in the establishment of a power station is costs associated with installation, while in otherwise normal situations, the efficiency of the power plant would be decisive.

The consequences of this process in the construction of a power station are displayed in the following figures. The cost of gas is assumed to be 30 Rials (at present in Iran). The purchasing cost of electricity from both power stations, combined cycle and gas-driven, are considered to be equal and fixed. The other data pertaining to the both types of power stations are obtained from true ratios.

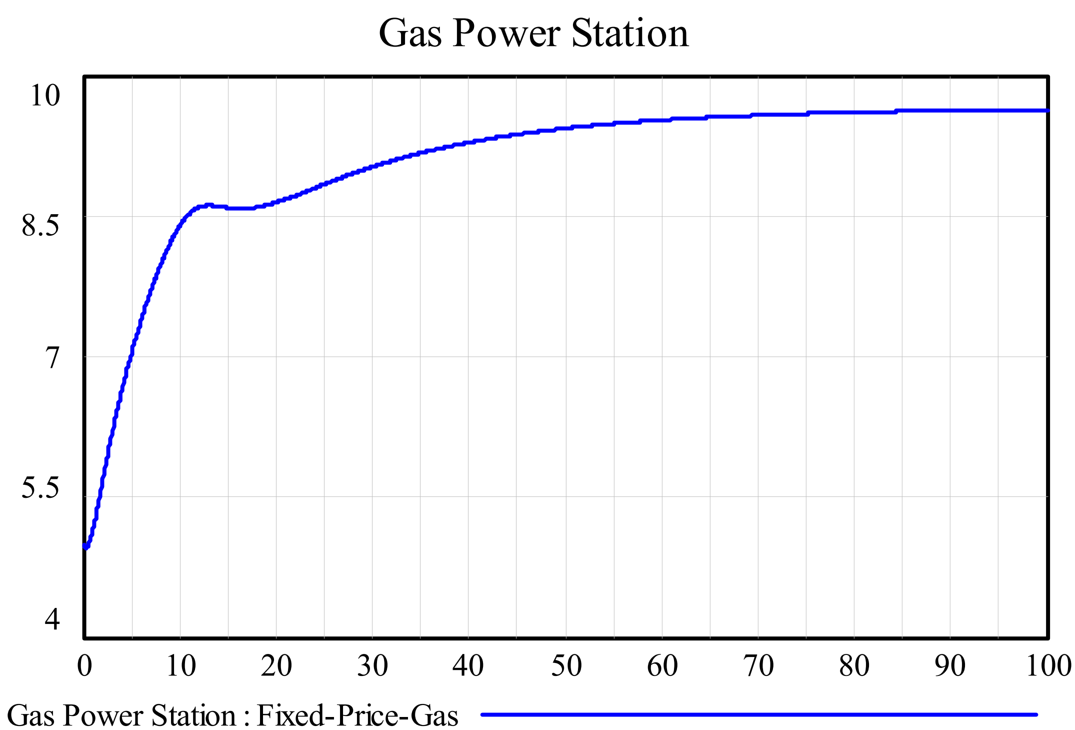

Figure 8: Gas Power Station.

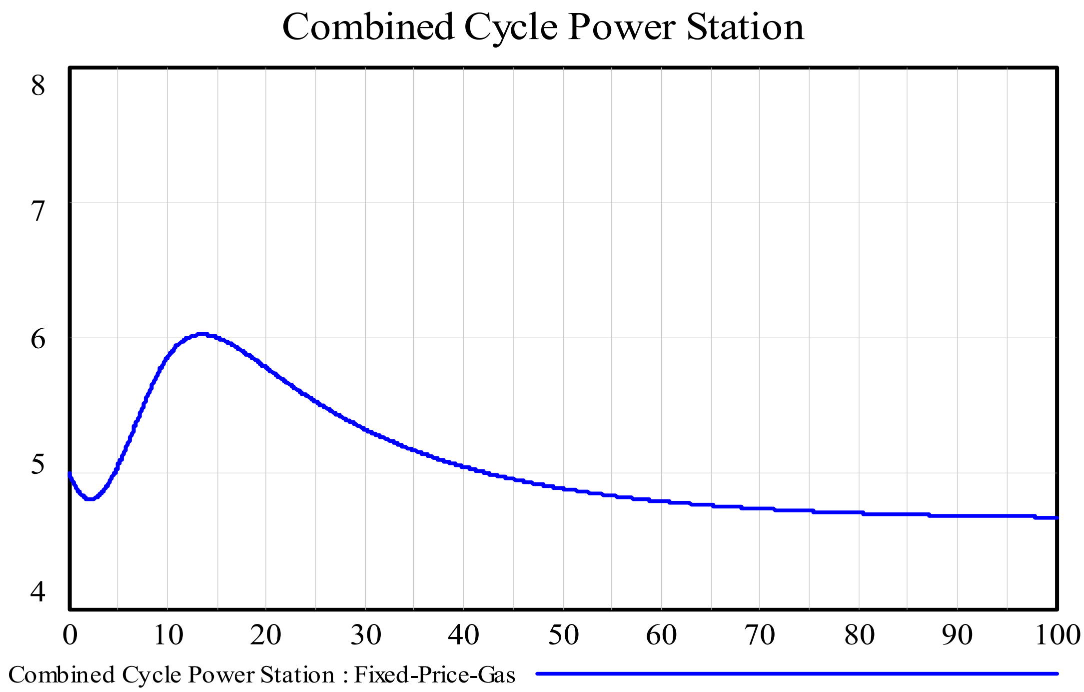

Figure 9: Combined cycle Power Station.

It is clearly obvious that the number of power stations with increased efficiency has not increased over time and power stations with low costs of installation have grown in number. The general growth in production is desirable and reflects the fact that current production is approaching levels of desired production. This process is demonstrated below.

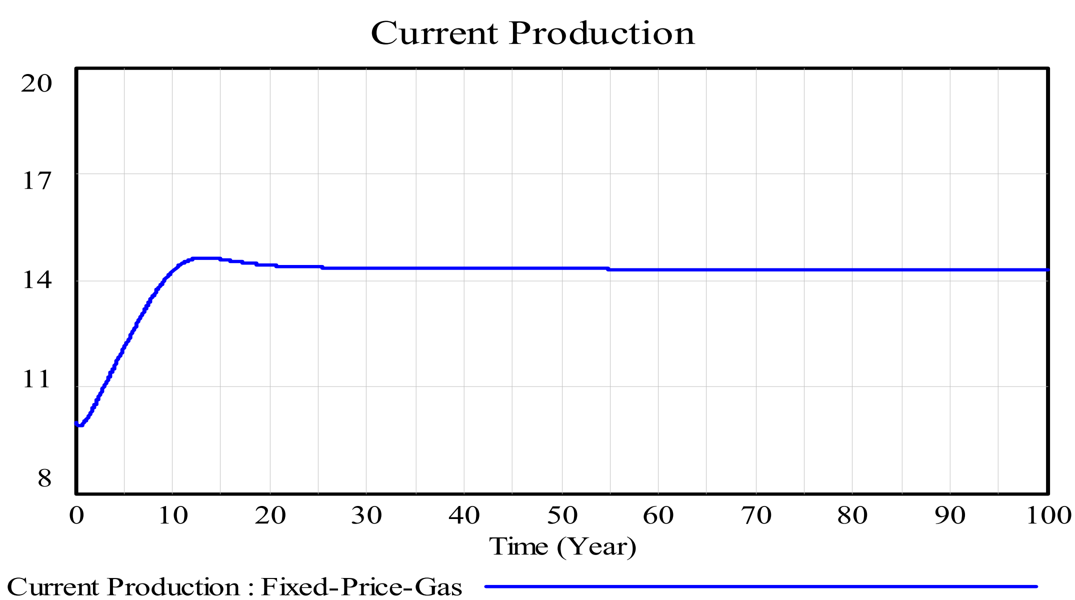

Figure 10: Current production.

However, this is occurring at the expense of decreased efficiency. Furthermore, in such a situation, since more and more power stations are created, the costs for the government will also increase.

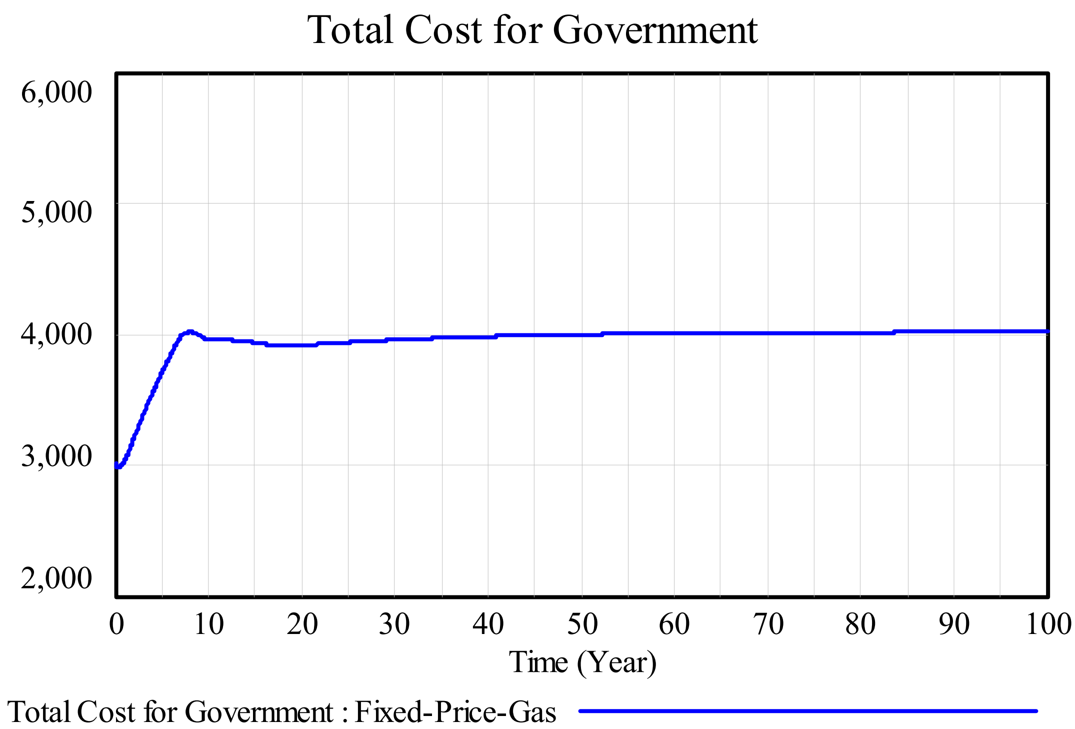

Figure 11: Total cost for government.

Policy formulation for solving the problem

In the preceding section, the prevailing conditions in Iran and the direction current trends are taking were shown. The increased costs fore the government will be inevitable. But the snag in the process is the increase in the number of gas-driven power stations in contrast with combined-cycle ones despite the fact that the production efficiency of combined cycle power stations is nearly twice as much as that of gas-driven ones. This leads to increased costs incurred for the optimization of gas-driven power stations and instead of a reduction in energy intensity an undesirable increase in energy intensity is observed.

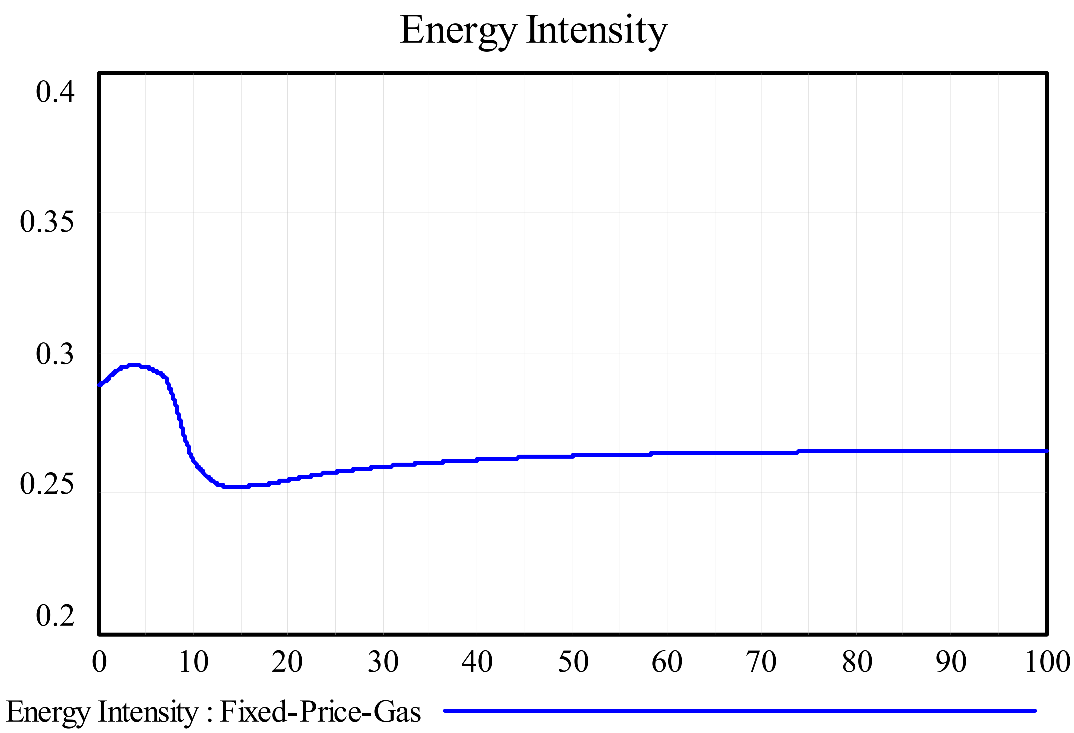

Figure 12: Energy Intensity.

But where does the problem stem from? As indicated earlier, the low price of gas makes the costs associated with the utilization of gas seem negligible when compared with the costs of installation and this issue leads to optimization being sacrificed for lowered costs of fuel. By selling gas at subsidized rates to power stations, electricity is bought for a low price and it is assumed that by decreasing the cost of gas, the price of electricity has been decreased. The only cost for the government is considered to be the subsidy granted to a power station for cost of producing electricity. This view has led to the growth in power stations with low efficiency as well as a surge in energy intensity. However in practical terms, the cost for the government is not only in the form of this subsidy but loss of possible revenue from exporting gas should also be added. This opportunistic cost is actually the difference between the profit obtained for the government when gas is exported and sold to other countries and the cost associated with selling gas at reduced prices to power stations.

It is necessary to note that under these conditions (low price of electricity), the government expends more for power stations with decreased efficiency which utilize more gas.

The solution we propose for this problem and the policy we suggest the government consider is that rather than granting subsidy on the fuel used for producing electricity at power stations, subsidy be granted for the purchase of electricity from power stations. In this way, obstacles mentioned above will be eliminated and the dynamics of power stations will move toward enhancement and decreased energy intensity. With this policy, the government is still able to exercise control over the price of electricity (to prevent pressure on the consumer). The only costs imposed on the government would be the subsidy offered for the purchase of electricity and no subsidy will be offered for gas utilized by power stations.

The general problem associated with subsidizing electricity is not of concern here and is beyond the discussion of this paper. However, by inducing the above changes, no change will arise in the cost of electricity sold to people and accordingly in the dynamics of subsidizing electricity.

We predict that the implementation of this model will lead to rapid movement toward combined cycle power stations, enhanced performance, decreased energy intensity all at the same or reduced costs for the government.

With the increase in cost of gas, the already existing gas-driven power stations will undergo losses. Therefore, at least for a limited time, the government should be supportive to such power stations. In order to support this sector, the government could consider greater costs for buying electricity from these units for a limited period of time within which these units can proceed through the stages of converting to combined cycle power stations. Obviously such support would be limited and time-bound.

Model behavior following implementation of suggested policies.

Here we explore the behavior of the model after the suggested policies are implemented. This behavior can be seen in the following graphs. First is the behavior of gas-driven and second is the behavior of combined cycle power stations, the growth in their numbers which will directly affect the process of the system.

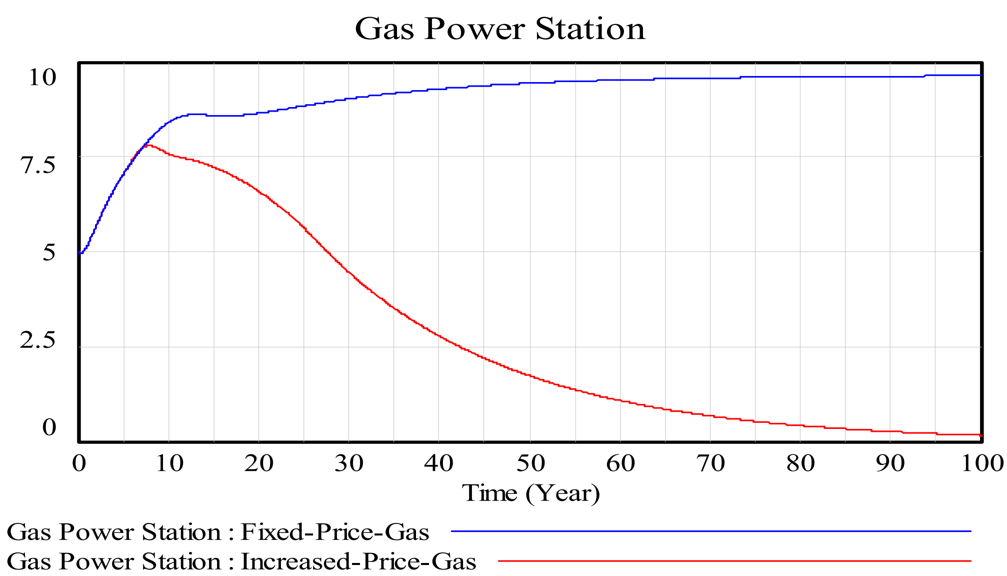

Figure 13: Gas Power Station.

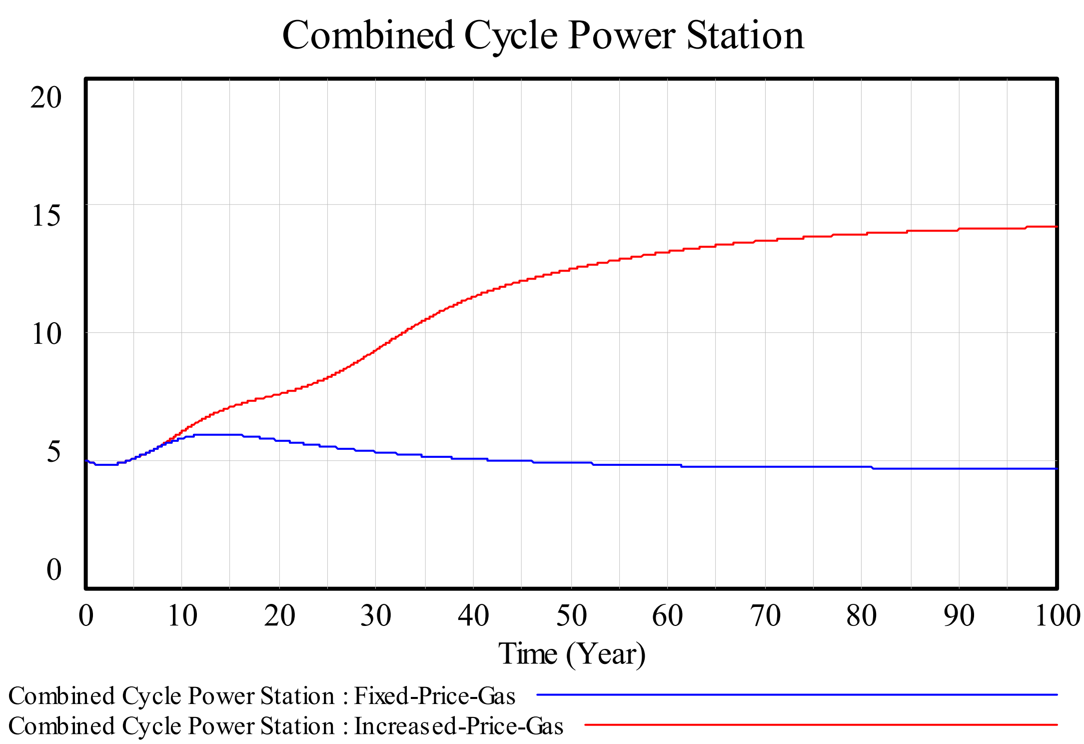

Figure 14: Combined Cycle Power Station.

As can be seen, this behavior is completely compatible with desirable behavior. This desirable process can also be observed with regard to energy intensity.

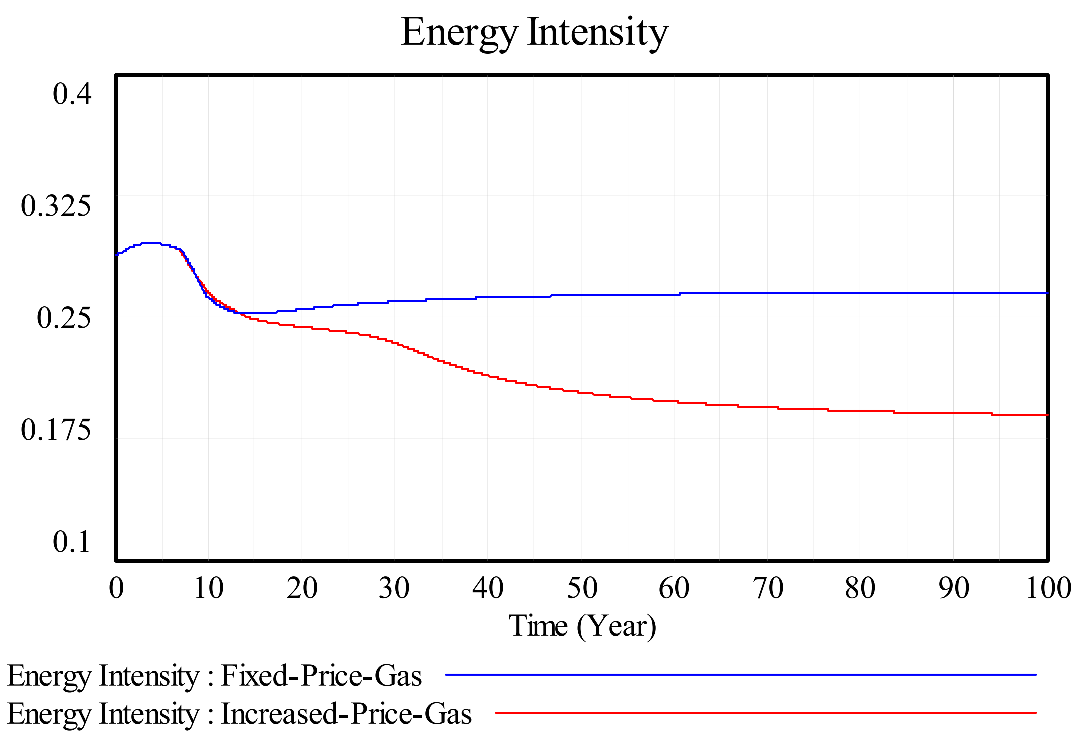

Figure 15: Energy Intensity.

Desirable trends are not restricted only to this area. The target we pursue includes controlling costs for the government apart from decreasing energy intensity and enhancing optimization.

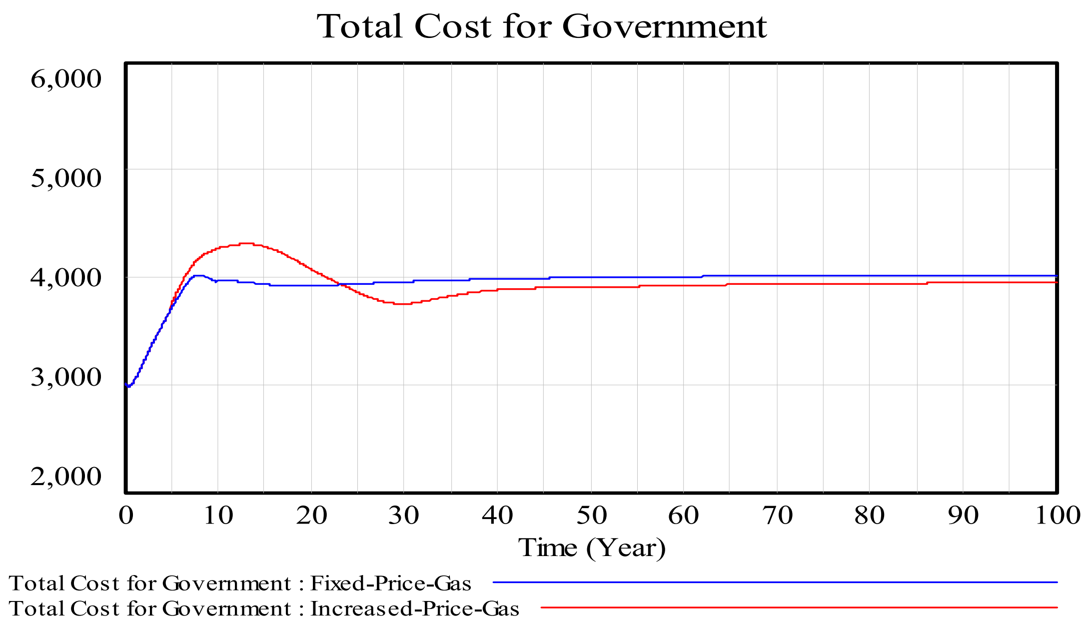

Figure 16: Total cost of government.

As can be seen, although costs for the government overshoot and undershoot, in the long run they tend to remain stable. The reason for this behavior is the same additional policy to provide support to gas-driven power stations. However, as demonstrated above, this amount of increase in costs is temporary and a large proportion of it is compensated for by the subsequent reduction is costs.

Conclusions

In contrast to the general assumption that when difficulties arise in an establishment, it usually has to do with a group of individuals who are the decision-makers, in many instances, it is the very structure of the establishment that creates problems. One such long-standing problem in Iran is the provision of subsidy to households for several consumer goods, which not only imposes a heavy financial burden on the government, but also results in excessive consumption, leading in turn to a regular rise in costs for the government. The elimination of subsidy from the economic structure of Iran requires time, incurs heavy social and economic costs as well as creating immense pressure on the government. That is why no government in Iran has been able to focus attention on tackling this issue. In the present paper, we first explored the difficulties associated with payment of subsidy for fuel utilized in power stations and demonstrated that a subsidy on fuel hinders optimization of power stations, which, in turn, leads to an increase in energy intensity in this sector. That is, the increase in energy intensity occurs on account of the low cost of fuel and inattention to optimization results from it not being economical to the investor. Next, we suggested a solution which not only circumvents the problem but also involves the least side effects and in the long run, lifts the financial pressure currently on the government. Therefore, rather than eliminating the subsidy, we propose a strategic and goal-directed use of the subsidy to achieve the optimization of power stations. In the suggested solution, fuel is supplied to power stations at the world price and we demonstrated that by raising the price of fuel, greater optimization of the production and efficiency at power stations would be possible, eventuating in a reduction of energy intensity in this sector.

Future directions

In this paper, only supply, that is power stations producing electricity, was taken into consideration. However, policy makers would be able to arrive at the best decisions only when the power industry is evaluated from the perspective of both supply and demand. As changes in subsidy will impact not only the behavior of producers but also that of consumers, a resultant increase or decrease in consumption is likely, but in our model, the behavior of the consumer is taken to be stable. In future investigations, we intend to analyze the impact of subsidies in the demand sector of electricity so that, by combining the two views on supply and demand, the functional role of government subsidies in the behavior of the electricity market may be clearly identified and the best policies for minimizing energy intensity and costs to the government as well as for maximizing production and consumer satisfaction may be formulated.

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