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Dynamic modeling of the effect of Vehicle Hybridization policy on carbon emission and energy consumption

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ABSTRACT

Subsidies in the energy sector and pollution caused by fuel consumption in major cities of Iran has led to the adoption of Hybrid vehicle (dual) policies to burn cars in Iran. Considering the costs of dual combustion policy and not receiving the desired output, other strategies such as creating a fuel basket or developing CNG vehicles should be considered. Secondly, in the process of dual combustion vehicles, complementary policies Also benefited. The policy of dual-burning cars has been implemented and pursued in the country for several years. Huge energy subsidies and severe fuel pollution in the country's major cities, which have made it difficult to manage the two, are the government's main drivers for implementing this policy. Due to the many effects of fuel on environmental issues, in this paper, after expressing the advantages and disadvantages of gas and dual-fuel vehicles, using the method of system dynamics, which is one of the methods of modeling dynamic and social systems, a dynamic model in We find out how dual-fuel vehicles affect energy consumption, energy subsidies and pollution by vehicles, and then by implementing this model in simulation software, we show that the continuation of this policy with the current trend is not responsive in the long run and can be a source of problems.

1. Introduction

Gasoline alternative fuel is a topic that has been discussed in the world for many years [1]. The main reasons for this issue's importance are concerns about depleting fossil fuels, environmental pollution, and current fuels' economic costs. According to its conditions and resources, one type of fuel is more widely used in each country. For example, in Brazil, one of the world's largest sugar producers, methanol extracted from sugarcane is the main fuel for cars. Due to the huge reserves of natural gas in Iran, gas fuels as an alternative fuel to gasoline have been considered. Among the benefits of this type of fuel, we can mention reducing subsidies in the transportation sector and reducing pollution and its costs. Considering the importance and effect of fuel in environmental issues, in this paper, by presenting a dynamic model, government policies in dual-fuel vehicles on environmental management and economic costs and energy consumption are investigated. Figure 1 shows the growth in the number of gas-powered vehicles in Iran and the world in recent years.

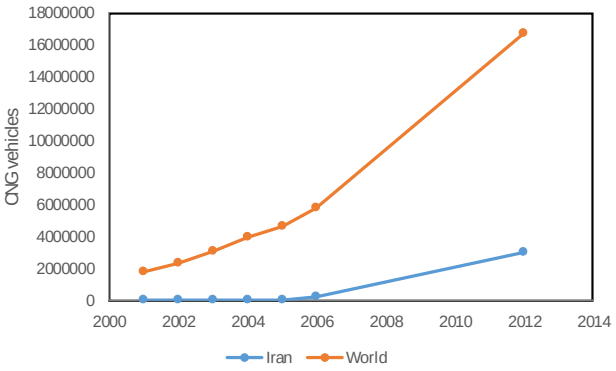

Figure 1. CNG vehicles in Iran and the world, since 2001 [2]

Due to the abundance of gasoline cars in the country, the cheapest and easiest way to gasify these cars is to double-

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burn them. The main problem lies in this point, which will be mentioned below. Note 13 Headquarters has been formed and in charge of this matter in line with the dual-burning program of cars according to the 2007 budget law [3].

2. Methods and material

2-1. Theoretical Framework

Vehicles that use natural gas as a fuel are divided into three categories:

Single burner with gas consumption: These cars work only with natural gas and have no other fuel.

Dual fuel: These cars are divided into two categories:

Gas-based: Gas-based engines are designed to work with gas fuel from the beginning. Since these cars' design is based on gas, all gas fuel issues and problems have been considered in their design. Therefore, if these cars' engine is optimally designed, it will have good quality and efficiency.

Gasoline-based dual-fuel: Gasoline-based dual-fuel vehicles (called dual-fuel for short) refers to those vehicles that have been converted from gasoline to gas-fired using a conversion kit. The original design of these cars was based on gasoline fuel. These cars' operation is such that the fuel can be changed from gasoline to gas when needed by using the gas kit. The fact that these engines are not designed to run on gas is their biggest problem. Because in their combustion, the characteristics of a gas engine are not seen, and it reduces the efficiency when working with gas fuel. Of course, some measures have been taken to overcome the above problems, making these engines' performance acceptable.

Hybrids: These engines are often obtained by converting a diesel engine to a gas engine. In such engines, gas first enters the combustion chamber at 90 to 95% of the total energy. When the air-fuel mixture inside the combustion chamber is sufficiently compressed and ready to ignite, a small amount of diesel is injected by the injector. This process causes the combustion to start and the engine to start. Diesel here acts instead of a spark plug and is therefore called pilot fuel or incendiary fuel. In these motors, each component is dependent on the other and can not operate without the other. Of course, there are other types of simultaneous diesel engines, such as gasoline-electric engines known as hybrid cars.

Fossil fuel vehicles have various pollutants, the main ones being carbon monoxide (CO), nitrogen oxide (NOX), and non-methane hydrocarbons. These gases are toxic and have adverse effects on the health of the body and the environment. Carbon monoxide combines faster than oxygen with hemoglobin in the blood and prevents enough oxygen from reaching different parts of the body. Other obvious side effects of this gas include headaches, irritability, and nervousness, which are well represented in today's society. Cancer, dirty clothes, premature decay of fabrics and paper, rapid corrosion of metals, and acid rain that destroys vegetation are other effects of these contaminants [3-5]. Its destructive effects on the brain and IQ reduction should also be considered one of these infections' relatively hidden effects.

Feyz [4] has compared the pollutants of fossil vehicles over the life of the vehicle. Carbon monoxide emissions from a gas-fired vehicle are approximately 80% lower, and those from nitrogen oxides are at least 70% lower than those from gasoline-burning vehicles. Emission of toxic pollutants due to gasoline evaporation from the car tank during refueling does not occur in gas vehicles. Natural gas has less carbon in the energy unit than other liquid hydrocarbon fuels, which emits less carbon dioxide over the same distance [5]. Esfahani [6] has investigated the amount of methane production and its effect on global warming in gas-burning vehicles and the reasons why so-called clean fuels are gaseous fuels. Goyal [7] states that CNG vehicles produce 70% less unburned hydrocarbons than gasoline vehicles. He also states that gas engines produce less noise pollution than gasoline engines that the higher the octane number of the fuel, the less pollution. A comprehensive 2016 study found that non-methane hydrocarbons and toxic air pollutant gases for gas-powered vehicles were about 0.1 times the same amount as gasoline-powered vehicles, while methane pollutants were about ten times the corresponding values for gasoline-powered vehicles. Fuel consumption for CNG vehicles was about 20% lower than similar gasoline vehicles [8]. Aftab site [9] deals with a 20% reduction in efficiency and a 30% reduction in the life of biFuel engines (if the relevant standards are not met) and its effect on increasing fuel consumption and pollution, and according to research Shows an increase in pollution in dual-fuel vehicles. According to the World Bank, when a gasoline-powered vehicle is converted to gas-fired, the amount of pollutants it emits within two years is greater than gasoline-burning engines [10]. In addition to the above, dual-fuel vehicles in Iran face more problems, some of which are as follows:

1. In Iran, several types of fixed kits are used to gasify all cars. These kits are not designed and adjusted based on the type of vehicle, and therefore cause more fuel consumption and combustion (incomplete combustion). According to international standards, one cubic meter of gas should be equivalent to 1.3 liters of gasoline, but in Iran, due to the incompatibility of the kit and the car, this amount is less than 0.9, which means a great waste of energy and resources, and create pollution.

2. In case of changing the fuel from gasoline to gas, there should be a system for burning the remaining gasoline inside the route and the engine, but in the equipment that is installed in Iran for dual-burning car, this is not

observed, and therefore these cars when changing Fuels burn out and produce carbon monoxide instead of CO2.

3. The research mentioned above has been done on cars that have been produced in the factory as dual-fuel. At present, in our country, many gasoline-burning vehicles are dual-fuel in workshops, which, as a result, have lower efficiency and quality, and their pollution and energy consumption are higher.

4. In cars that burn in dual workshops, the engine's power loss is more than in factory cars. Therefore, some drivers, to increase their engine power, remove the catalytic converter parts (converter catalyst), which causes a sharp increase in vehicle pollution[9].

2-2. Dynamic model

Forrester introduced the System Dynamics Methodology [10] at MIT in the early 1960s. This approach, which is suitable for examining the dynamic behavior of complex physical and social systems, helps to better understand processes, causal relationships, and the long-term effects of decisions and policies by emphasizing the feedback and delays in these systems. In contrast to the linear view, the systemic view, which is the basis of this methodology, states that the disability also affects its cause and forms feedback loops in many cases. Figure 2 shows an example of the difference between these two types of views. As can be seen in this figure, in a linear view, an increase in the price of a commodity reduces its demand in the market, which in turn forms a negative (inverse) causal relationship. But from a systemic point of view, the problem does not end here, but the decrease in demand, in itself, reduces the price of goods and creates a negative causal loop. References 14-12 provide more information about this methodology.

In this section, based on the available information and with the help of system dynamics methodology, we try to obtain a dynamic model about the effects of dual-burning cars in Iran on the rate of pollution and energy consumption. This model can help recognize the causal relationships of variables and the impact of factors on each other and be a good basis for examining the effect of different policies on these cases. This paper's modeling process is the Sterman method [6], shown in Figure 2. Two factors can be identified as the main drivers: air pollution in metropolitan areas and fuel consumption and related costs to implement dual-burning cars' policy. These two factors make the government want to replace gasoline with fuel, and government facilities and laws create public demand.

Since this article investigates the environmental effects of the dual-fuel car burning policy, the emphasis in modeling will be on the cause of pollution, and the factor of fuel consumption will be mentioned as one of the causes of pollution. Figure 2 shows the reasons for the government's willingness and public demand for alternative fuels. In addition to imposing pollution costs (such as treatment costs), the level of pollution also creates a social pressure to reduce pollution.

Due to the increase in government spending in the fuel sector, the policy of quota gasoline and the supply of non-quota gasoline at a higher price was implemented in the country, which, to some extent, changed the pattern of fuel consumption and reduced gasoline consumption at home. Loop B1 in Figure 2 shows this. As shown in Figure 2, the government's desire and demand of the people and the huge gas resources inside, and the low cost of its distribution in the country have created the demand for gas-burning vehicles. Given a large number of gasoline vehicles in circulation in the country, there are two solutions to meet this demand for gas vehicles:

1- Replacing gasoline-burning vehicles with gas-powered vehicles

2- Conversion of gasoline-burning vehicles to dual-fuel vehicles by installing a conversion kit and gas tank

The first method is expensive. Of course, gas-based engines have been designed and manufactured in the country, and gradually, new cars will be introduced to the market with these engines, but replacing the current gasoline cars with these cars means imposing costs on the owners of gasoline cars, which currently, according to With the relatively low price of gasoline, there is no incentive to do so. Therefore, the government's desire and the demand of the people have been towards the second method and turning cars into dual fuel. As mentioned in the previous section, these cars' fuel consumption is not optimal and will increase fuel consumption and pollution [5]. The rings R1 and R2 in Figure 2 shows this.

In addition to the above factors that affect the government's willingness, other factors increase people's demand due to the increased number of dual-fuel vehicles. These reinforcing factors and loops are shown in Figure 6. Establishing infrastructure and related equipment in the country, due to increasing the number of dual-fuel vehicles (R3 ring), creating production capacities due to increasing demand for gas vehicles (R4 ring), reducing the automaker's incentive to optimize or alternative fuels, due to creating production capacity for Dual-burners in themselves and component makers (R5 ring) and the slow growth in the number of base gas engines, due to lack of motivation in the automaker (R6 ring), are the factors driving the demand for dual-fuel vehicles [3, 4].

Because the world's natural gas resources are limited, few international automakers produce gas-powered vehicles. Thus, the lack of an actual foreign competitor

exacerbates this motivation among domestic automakers. Besides, the lack of strict environmental regulations at home leaves the automaker free to produce the same type of non-optimal vehicles and does not provide a platform for investment in improvement projects.

Due to the high technology and high price of gas-burning equipment and the relatively low price difference between quota gasoline and CNG in the country, there is not much incentive to buy gas-powered vehicles. As a result, the automaker invests in this field. It is government pressure that has driven carmakers in this direction. Therefore, the capacities related to dual-burning cars have been formed more in the parts manufacturers, and the car manufacturer has not built a special capacity [1].

A factor that can prevent the spread of dual-fuel vehicles is its number of base gas engines. But as shown in Figure 2, the low motivation of domestic automakers and the limited number of foreign manufacturers for this type of engine have led to a small number of these engines in the market and, as a result, an increase in the number of dual-burners. Figure 2 shows a complete model of the causal relationship between the factors that drive alternative fuel demand and the number of dual-fuel vehicles.

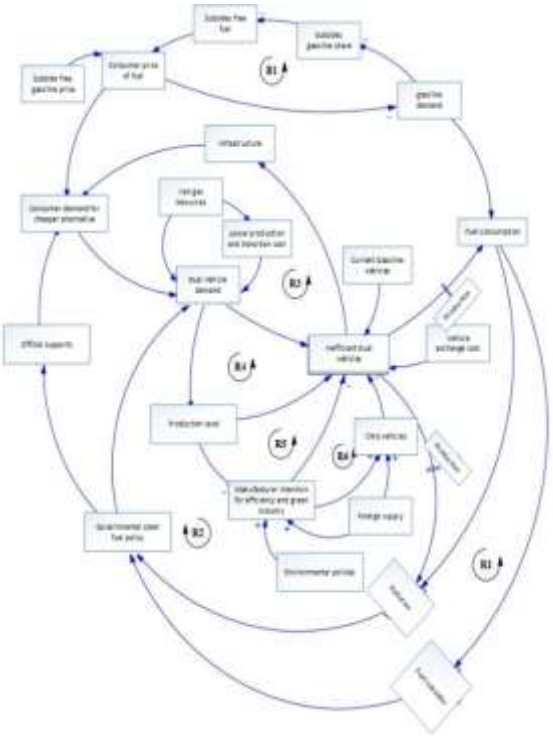

Figure 2. A causal model of factors affecting the number of dual-fuel vehicles

3. Dynamic Transfer pressure to temporary solution Model

One of the well-known behavior patterns mentioned in system dynamics is the pressure transfer pattern [2]. This model states that temporary solutions remove attention and pressure from the underlying solutions. Temporary solutions to the problem signal temporarily and calmly relieve the neglecting system to address the problem's root (Figure 3). Because basic solutions are more difficult and require more effort than temporary solutions, people are attracted to temporary solutions. But expanding the root of the problem and reducing the ability to take basic action can exacerbate the problem's root. This theme and model are shown in Figure 3. The purpose of referring to the pressure transfer pattern in this paper is to show that pollution and energy costs are not the main problem but are themselves symptoms of a problem that has manifested itself with a relatively long time lag. From this point of view, the root of the problem is the non-optimal fuel consumption in cars. The production of relatively high-consumption cars and the lack of attention to the car's technical settings have caused the fuel consumption in cars to be non-optimal and increase costs and pollution. In these circumstances, dual-burning cars are only a temporary solution, and the basic solution is to use optimal cars (Figure 3). Figure 3 shows the side effects of this temporary solution, which in the long run will spread the root of the problem and make it more difficult to implement the basic solution. Creating production capacity and related equipment creates inertia for domestic automakers in the face of change. This makes it more difficult to achieve the basic solution, producing fuel-efficient and fuel-efficient vehicles [5]. Besides, with the proliferation of dual-fuel vehicles, these vehicles' owners have become accustomed to this situation and resist changing circumstances. Another complication of the increase in the number of dual-burners, due to the low price of gas, is the spread of the culture of free fuel, which makes people less sensitive to fuel consumption and, as a result, the root of the problem, i.e., non-optimal fuel consumption in cars [6].

Another thing to note is that various pollutants, such as air pollution, noise pollution, heat production, and global warming, which are all part of our country's environmental problems and the world in the last century, are not created for free! This means that to create the same problems, you have to pay a lot of money and consume more fuel. Due to government subsidies, this cost is not noticeable for consumers, and therefore they are not willing to pay more initial cost to buy more efficient cars. As a result, domestic automakers have no incentive to invest in it. As shown in Figure 3, the best way to deal with these environmental problems is to deal with free fuel culture. This means that if consumers and owners of private cars find that the cost of air pollution is too high for the life of their car, they will be willing to pay a small portion of the cost when buying a car or for inspection and adjustments. Technically reduce their fuel consumption and use more efficient vehicles. Creating demand for fuel-efficient vehicles has led to domestic automakers' supply and allows them to enter global competition [7].

3-1. Simulated Model

The third and fourth steps in the Sterman method are to implement the model in software and then simulate it. In this article, Vensim software is used. This makes it possible to simulate the current situation and examine the effect of different policies on the article's factors, namely the increase in pollution and the number of fuel subsidies paid [7]. To create a real model, you need comprehensive and accurate information such as the number and types of vehicles available in the country being produced and imported, the amount of fuel consumed and their cost, traffic situation, and increasing fuel consumption. Since this paper's main purpose is to show the general effect of dual-fuel vehicles' policy on fuel consumption and pollution, the following model is simplified as possible and only simulates the variables' general behavior in question. ., by adding the above information to the model, more accurate simulations and conclusions will become more realistic and tangible, which is our suggestion for future work and supplementary articles. Appropriate information on Vensim software and rate and state variables is given in [5]. Figure 3 shows the total number of vehicles as the sum of gasoline-powered vehicles, gas-fired vehicles, dual-fuel vehicles, and other fuels. Each of these cars will be scrapped at a certain rate. Besides, existing gasoline vehicles are converted to dual-fuel vehicles at a certain rate. Figure 3 shows the complete model by adding the factors that motivate the government, namely fuel costs and subsidies, the amount of pollution, factors affecting public demand, and other variables discussed in the previous section. In this model, it is assumed that dual-fuel vehicles use only quota fuel, and gasoline-powered vehicles use non-quota gasoline in addition to quota gasoline. Since the government currently pays a subsidy for this type of fuel, the subsidy's effect is also included in the model. As mentioned, in this model, relatively simplistic assumptions are used. For example, the rate of increase in the number of gasoline-burning vehicles and vehicles with other fuels, subsidies for other fuels, pollution reduction rates, world gasoline prices, free gasoline prices, and gasoline quotas for gasoline and dual-fuel vehicles are assumed to be constant. To increase the validity of the model and to examine more precisely the effect of different policies on the target variables (Step 5 of the Sterman method), in addition to changing some of these variables that are assumed to be fixed, public and private vehicles with different fuel quotas Be separated. Assuming there are 6 million gasoline-powered vehicles, 260,000 dual-fuel vehicles, an annual increase of 800,000 gasoline-powered vehicles, and an annual production of 650,000 dual-fuel vehicles, the values of important variables (fuel costs and subsidies, number of vehicles in the country, fuel pollution, and dual-rate pollution), Will be as shown in Figure 3. As can be seen, despite the reduction in pollution caused by gasoline-burning vehicles, the overall rate of increase in pollution is growing, which is due to the creation and increase of pollution from dual-fuel vehicles. The change in behavior observed in 2012 is because according to this model's assumptions, by 2012, all gasoline-burning vehicles in the country have been double-burned, and after that, only the same 800,000 gasoline-burning vehicles that are produced every year are traffic is in the country. It is also observed that due to the relatively high gasoline quota of dual-fuel vehicles and their increase, despite the decrease in the number of gasoline-burning vehicles, the fuel sector subsidy as a whole is increasing.

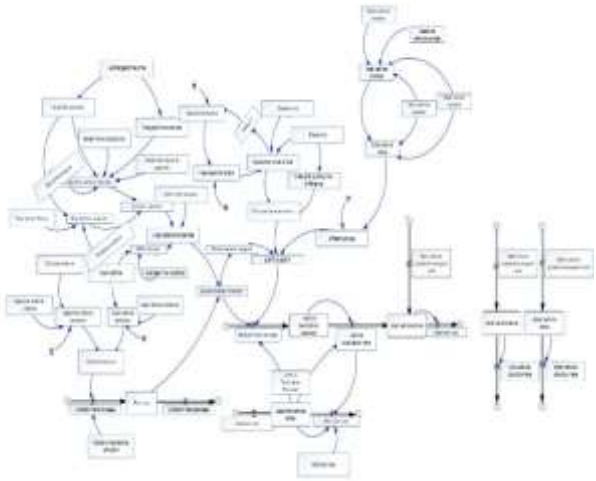

Figure 3. The complete model implemented in Vensim software

4. Results and Discussion

One of the most important parts of system dynamics is model validation. Ensuring the model's validity is a necessary precondition for ensuring the validity of the model's results. Several tests have been designed to validate dynamic models divided into two categories: structural and behavioral. Structural tests examine the validity of the model's totality and structure, and behavioral tests examine the validity of the behavior and model outputs. We can mention the parametric model tests, boundary adequacy, and limit conditions among the structural tests. Sensitivity analysis, an important test to measure the validity and reliability of various models, reflective behavior, contradictory behavior, and behavior prediction, is also among the behavioral tests. [9] discusses the validation of dynamic models in detail. Besides, in the methodology of system dynamics, the type of relationships between variables and the validity of numerical values are determined in focus groups [1] consisting of experts in the field [4]. For this model, several focus groups have been formed in this regard. Numerous tests have been used to evaluate this model's validity and reliability, but for the sake of brevity, all of them and their output diagrams have been omitted. Limit conditions test: In this test, by determining the initial values of the variables in the limit state, the stability of

the model behavior is checked. If the cost of quota gasoline and the price of free gasoline are at their lowest, air pollution will increase. Pollution decreases as costs and prices increase [11-15]. This is similar to what the model is expected to show. If the average life of dual-fuel vehicles is reduced, air pollution will be reduced, as expected. Behavior sensitivity test: with minor changes of the model variables, the output behavior shows changes based on weight and the variable's impact on vehicle pollution and does not have unpredictable drastic changes.

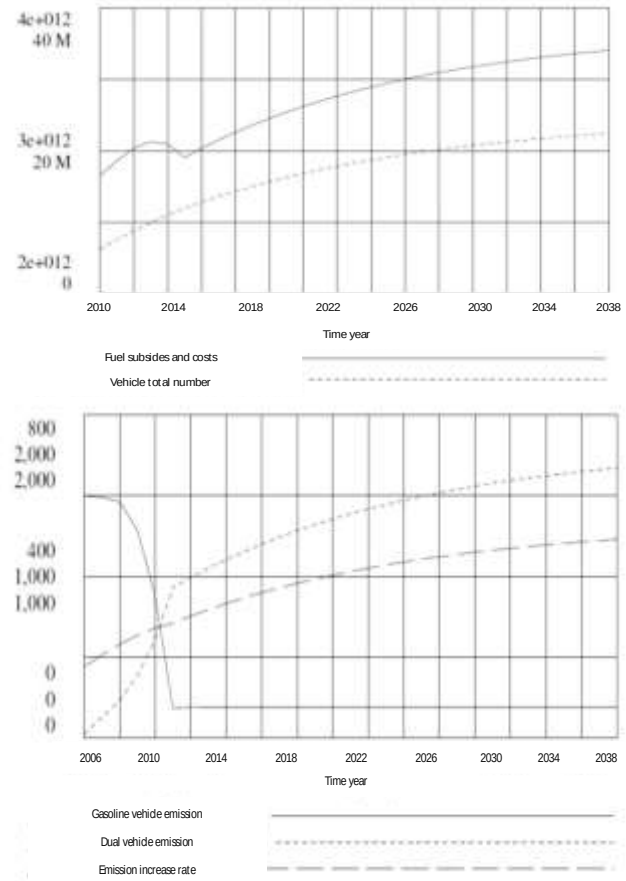

Figure 4. (a) Rates of pollution increase (b) Total number of vehicles and fuel subsidies

This article investigates the dual effect of burning cars on pollution and fuel consumption in the country. As observed, the dynamic model allows for better and easier analysis of the long-term effects of dual-burning policies by removing the time barrier and approaching the distant future. According to the data and model presented in the article, it can be seen that the policy of dual-burning cars only reduces the growth rate of subsidies and pollution and does not solve the problem radically. In addition to this discussion, the policy of dual-burning cars has other points and side effects that need to be considered. Some of its environmental points and consequences are mentioned below.

It seems that in the case of a temporary solution to double-burn cars, there is a risk that the scenario of gasoline and LPG will be repeated in the country. In other words, if CNG is not used optimally in the country, many problems will arise after a few years, and then, at a high cost, a new solution and alternative must be sought. As mentioned, the abundance and cheapness of gas prevent anyone from thinking about optimizing fuel consumption (which was mentioned as the basic solution). While simple things like adjusting the tire pressure, using the right gear while driving, changing the air filter and engine oil on time, and turning off the car while stopping can greatly reduce fuel consumption, for now, such cases are very cheap. It will be given. Studies by the Ministry of Petroleum show that 30 to 50% of energy consumption in the transportation sector can be saved by applying appropriate strategies, including replacing old car production methods with new methods. Figure 5 shows the average fuel consumption of cars in Iran and the world.

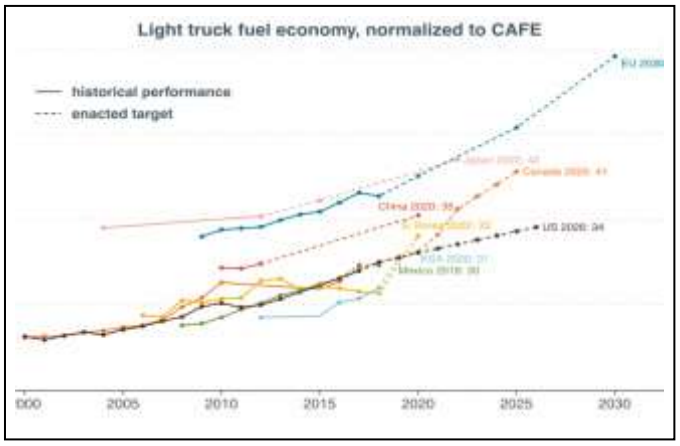

Figure 5. Comparison of fuel consumption of some light vehicles with the world average

One indicator of energy efficiency is energy intensity, which is defined as the amount of energy equivalent to crude oil used to generate $ 1,000 in GDP. Figure 6 compares energy intensity in Iran and several other countries in the world. In 2002, Iran's energy intensity was 322 tons equivalent to crude oil at a fixed price in 2000, while in China it was 217, in Germany 161, in the United States 227 and in Japan 156 tons equivalent to crude oil.

Although dual-fuel vehicles reduce air pollution, with the expansion of their number and the passage of several years of operation of these vehicles, as we saw in Figure 7, the pollution from these vehicles will intensify. Therefore, to solve this problem, there is no way to ignore the basic solution to optimize fuel consumption. To achieve both our goals of reducing energy costs and reducing air pollution, two general strategies seem to be pursued:

- Strategy for creating a fuel basket in the country
- Development strategy of CNG vehicles

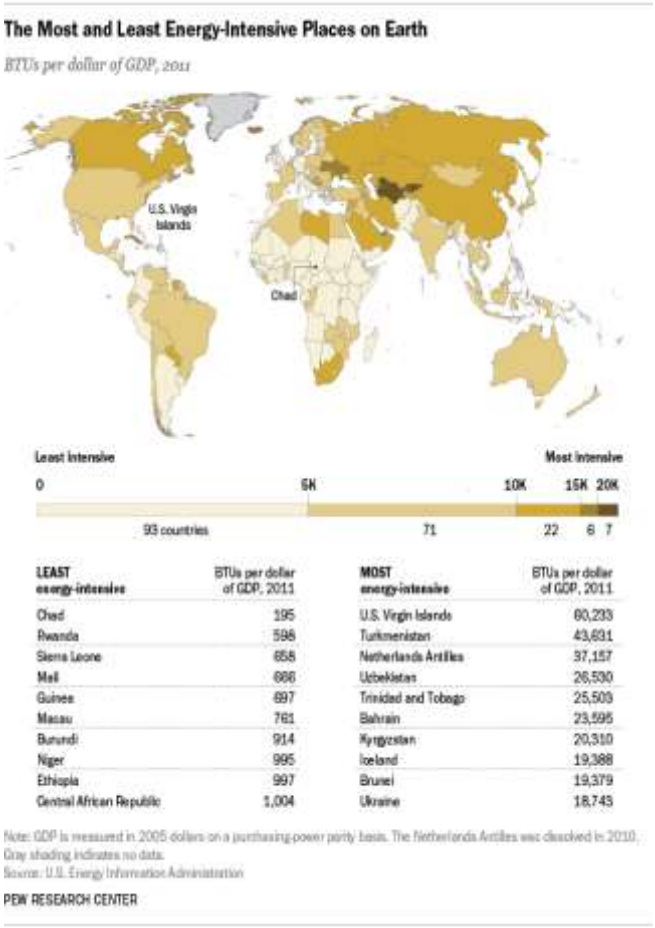

Figure 6. Energy intensity in Iran and selected countries in 2011

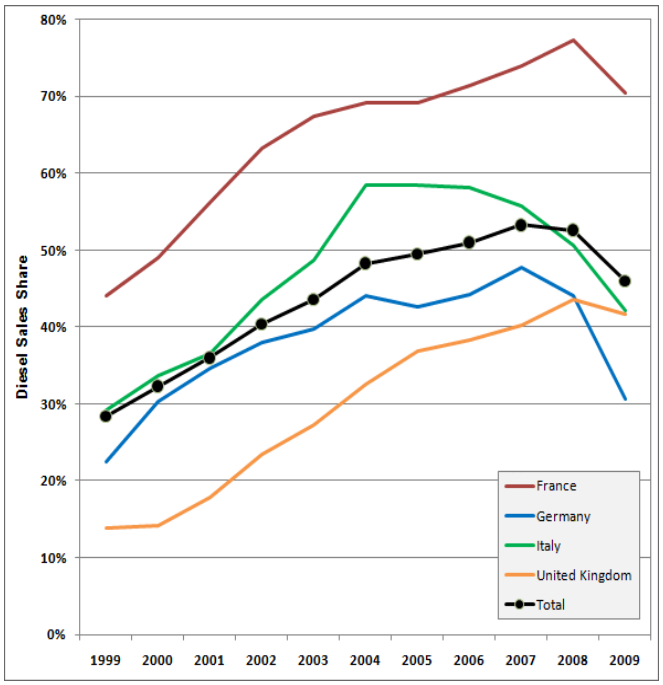

Figure 7. Sales share of diesel vehicles in Europe compared to total production vehicles

Compared to the second strategy, the costs of this strategy in our country are high, and therefore investing in it has no economic justification. As for the CNG strategy of burning cars, it seems that the best possible policy is a step-by-step development policy. That is, instead of creating a double-burning wave in the country, it is better first to test several gas-fired vehicles and study their performance, fuel consumption, pollution, and other important issues, the country's strengths and weaknesses, and the bottlenecks in this He identified the field and then, with full awareness and ability, moved towards expanding the number of gas-powered vehicles. For this purpose, high-consumption public vehicles have priority. In other words, the proposed policy is that at this stage, and given the current dual-fuel capacity in the country, the government should only gasify public transport vehicles. In this way, due to the difference in gas and gasoline prices, people will be encouraged to use public transportation, and as a result, both fuel consumption and costs will be reduced, as well as traffic, pollution, and their overt and covert costs. Besides, it is possible to study the mentioned cases well. Due to the smaller number of public vehicles, long queues in front of gas stations are also avoided. We can focus on car gasification technology, gas-based engines, and stations' development during this time [21-26]. Regarding the strategy of gasification of cars, in addition to the above hierarchical policy, the following policies can also be considered as complementary policies:

- Investing in CNG technology in the country: establishing research centers, attracting doctoral students, and familiarizing the community with the technical knowledge of this type of fuel can lead to full access to this technology and current problems, such as difficult transfer of reservoir technology (due to usability From it in the military industry), will rise [27, 28].

- Creating regional synergy: Around Iran, there are other countries such as Russia, Turkey, and Pakistan, which in addition to having gas reserves, are burning their cars. Cooperation with these countries can be beneficial in technology transfer and reduce costs and expand the market [29, 30].

- Reduction of gasoline quota for public cars: This policy encourages this type of car to burn their car [31, 32].

5. Conclusion

Finally, regardless of the chosen strategy, it is necessary to pay attention to fuel consumption and sensitize society. In this regard, the production of cars with gas-based engines, which also use gas optimally (low-consumption cars), and the application of stricter rules on the amount and manner of cars' fuel consumption can be effective policies. Currently, cars are classified

based on the amount of gasoline consumed, and this classification does not exist for the total amount of energy consumed. Creating this classification and using energy labels can create sensitivity in society and change fuel consumption patterns. It is also important to note that given the government's investment in developing dual-fuel vehicles, if the right policies are not adopted now, it will be very difficult in the coming years to increase the number of vehicle changes and improve conditions.

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