Improved Energy Efficiency and Environmental Safety of Transport Through the Application of Fuel Additives and Alternative Fuels

G. Genon, E. Magaril, R. Magaril, D. Panepinto, and F. Viggiano

1 Introduction

The global nature of anthropogenic challenges related to a rapid depletion of nonrenewable energy resources and related environmental pollution requires a new priority of economic development with the ecological imperative to prevent catastrophic consequences. The interdisciplinary nature of this problem requires the formation of a program of improving energy efficiency and environmental safety of transport, which is one of the main consumers of fossil fuels and emitters of toxic pollutants and greenhouse gases into the environment. Such a program should include a set of technological measures aimed at improving the quality of traditional motor fuels and the use of alternative fuels. The specific methods will differ depending on the specific conditions of the country considering the environmental-economic efficiency.

The Environment Action Programmes of the European Union [1] aim to achieve levels of air quality that do not result in unacceptable impacts on human health, and consequent initiatives have been adopted; but, despite these efforts, current air quality in Europe still leads to adverse impacts, such as exposure to particulate matter and ozone, damage to materials and cultural heritage, and impacts of persistent organic pollutants on human health. In Figs. 1 and 2 [2], an illustration is reported about the emission trends of selected pollutants and the contribution that different sectors make to emission of these pollutants. From these figures, it is clear

G. Genon · D. Panepinto · F. Viggiano
Politecnico di Torino, Turin, Italy

E. Magaril (✉)
Ural Federal University, Yekaterinburg, Russia

R. Magaril
Tyumen State Oil and Gas University, Tyumen, Russia

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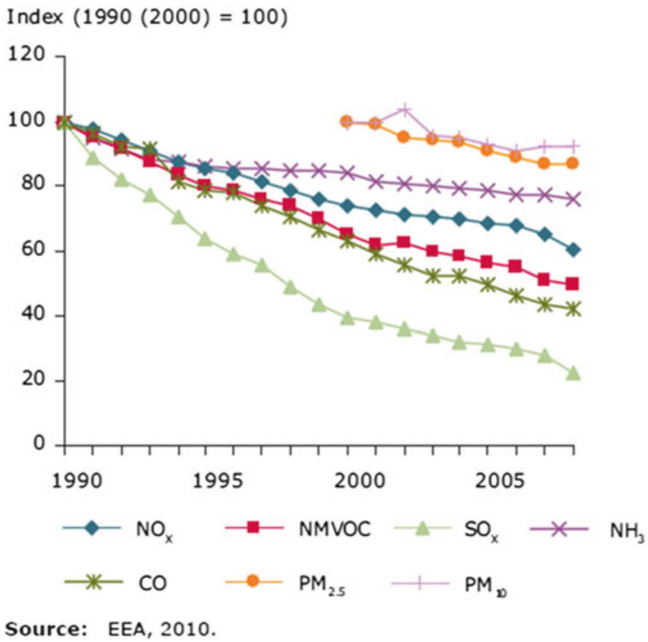

Fig. 1 Emission trends for selected air pollutants, EU 27 [2]

that road transport, as concerns the air quality, is a significant contributor, besides other negative aspects, chiefly to tropospheric ozone precursor emissions.

As a consequence of these concerns, the European Union in the past 20 years has developed and implemented policies aimed at a cleaner vehicle fleet, by defining exhaust emission limits for new cars, developing abatement technologies, and implementing plans for modification of transport and movement paths in the cities.

In consideration of the fact that a large part of EU population [3] lives close to roads with a large year vehicle traffic and that standards for PM_{10}, $PM_{2.5}$, and NO_x are in many areas at the moment not attained (as it can be observed from Ref. [4]), it is clear that some other interventions are required, in order to obtain a higher sustainability in road transport.

On the other hand, transport is responsible for more than 20% of total greenhouse emissions in EU [5], on account of the fact that an increased transport volume leads to a higher effect in comparison with efforts directed to more efficient cars. Concerning this aspect, besides initiatives in direction of a higher car efficiency and a lower fuel consumption (in Fig. 3, from Ref. [6], an indication in this sense can be observed), it is clear that the general approach directed to nonfossil fuels and renewable forms of fuels and energy can have a positive and useful application, like in large combustion plant and in strategies for thermoelectric production, also in the scenarios of alternative, renewable, nonfossil automotive fuels.

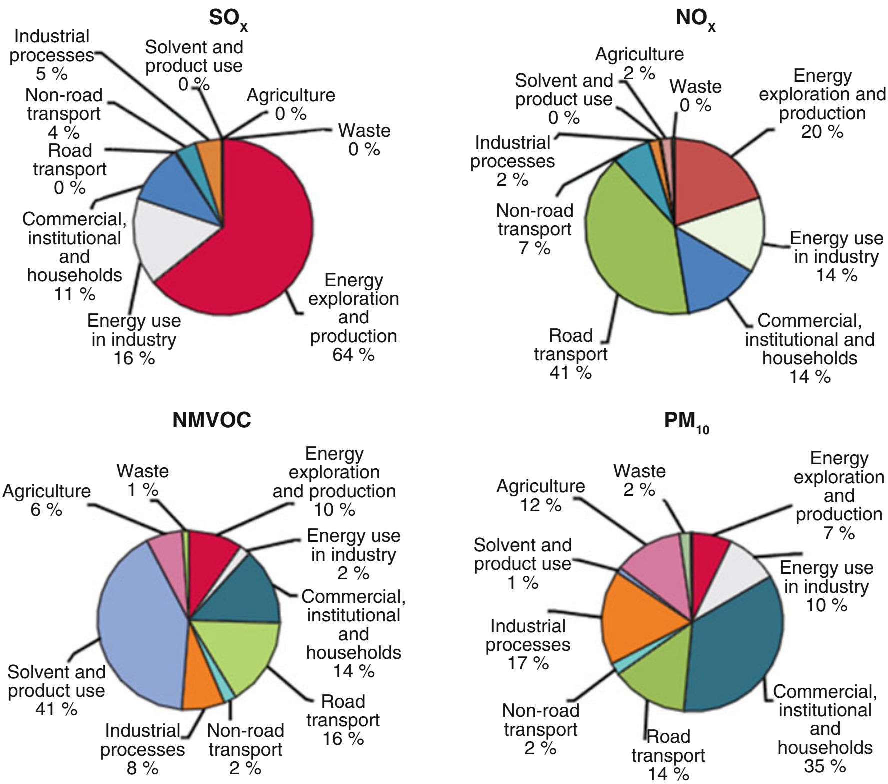

Fig. 2 The contribution made by different sectors to total emissions in 2008, EU 27 [2]

2 The Current State of Research on Improving the Transport Energy Efficiency and Sustainability

The basic areas of the current investigations in improving environmental safety and energy efficiency for the transportation facilities are an optimization of the structure and an improvement of the characteristics of the vehicle fleet (including an improvement in the design of engines and vehicles themselves and equipping cars with catalyst converters, etc.); an improvement of the maintenance system, road network, and traffic management, reducing the negative impact of climatic conditions; and an optimization of speed limits, improving the environmental characteristics of fuels, including an improvement of the quality of traditional fuels by refining methods, by the use of fuel additives and alternative fuels and energy sources.

The influence of various constructional and technological parameters on environmental and operational characteristics of transport was precisely investigated (including the works of Russian scientists Trofimenko [7], Erokhov [8]), and research in this area continues. Taking into account that any modernization in the design of engines and vehicles cannot be effective enough with low quality of fuels,

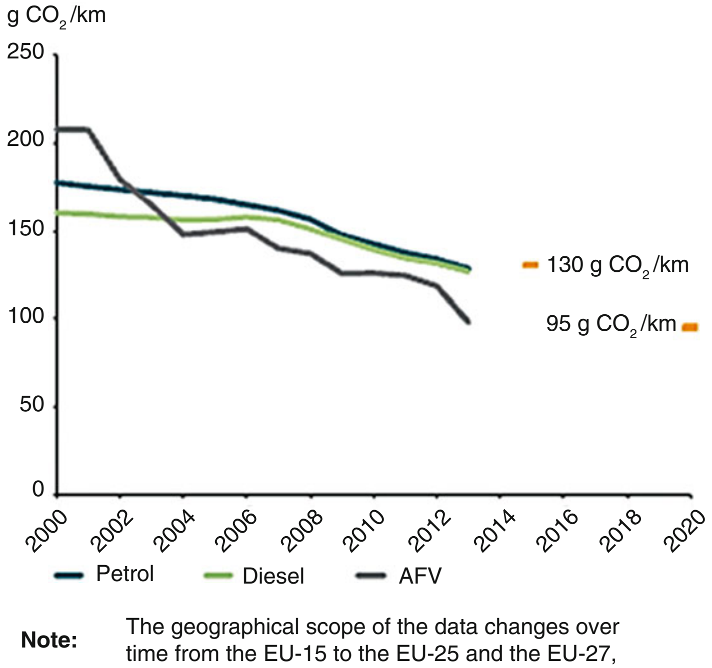

Fig. 3 Evolution of CO_2 emissions from new passenger cars by fuel type (EU 27) [6]

an improvement of the quality of conventional motor fuels and the search for possible alternatives are a priority. Many investigations are devoted to the fuel quality issue [9–14] and to the potential improvement in the quality of motor fuels by oil refining industry [15–18]. However, reformation of the refining industry requires huge investments and is acceptable only for rich countries.

One of the least expensive, fastest, and most efficient ways to influence the properties of gasoline and diesel fuels is the use of fuel additives, which provide the same or greater effect in comparison with the changes in the technology [12–14, 19–22]. All US refining companies, for example, introduce into the motor fuels produced additives, advertising the benefits of improved fuel quality,without revealing the additives' composition. The presence of hundreds of patents on additives for motor fuels and huge nomenclature of additives on the market demonstrates their great potential in correction of the motor fuel properties. Meanwhile, some of the proposed additives, improving one property of motor fuel while degrading others, become the reason of corrosion, gum formation, increased the cost of fuels, and so on and so forth. Apparently, the development of additives for motor fuels to improve their environmental properties does not acquire an adequate scale due to aggressive introduction of catalyst converters. Meanwhile, the use of catalyst converters increases fuel consumption; moreover, there are problems in their use at the low level of the fuel's quality and control.

It should be noted that research in the development of fuel additives are carried out mainly by large companies (such as ExxonMobil, Chevron, NewMarket Corp, Lubrizol Corp, Baker Hughes Inc., Shell, BASF AG, Honeywell Inc., The Dow Chemical Com, BP PLC); the authors of inventions are employees of companies and do not have rights to publish scientific papers, and the results of investigations are presented in the patents.

Accessing patent data indicates that different organizations have focused their research on various categories and areas of application of additives – detergent, antioxidant properties, and others. There is also some further research on catalysts. Chevron, General Electric Co, Massachusetts Inst., Shell, and other companies have progressed in the direction of the development of nano-additives to reduce engine wear.

In order to limit the exhaust emissions, many oxygenated additives have been proposed and a careful assessment of their efficiency has been made, but subsequently, in many cases, they cause secondary toxic emitted pollution [23]. Chiefly oxygenated compounds have been considered in this direction, in the first time with a large use of MTBE [24], now with higher interest in alcohols, chiefly ethanol and butanol.

The evaluation of effects of addition of these components on emissions, both regulated (particles, NO_x, CO) and unregulated substances (aromatics, aldehydes, unburned additives), has been studied, on different scale of application and with different ratios of introduction in fossil fuel of the improving agent.

For example, concerning the ethanol addition, a careful study has been conducted by Manzetti and Andersen [25], by individuating the effects of addition on over-indicated regulated and unregulated emissions and also the consequences from the catalytic efficiency of the post-combustion systems.

A decrease of exhaust emissions has been individuated by the addition of oxygenates, with emphasis on NO_x, CO, THC); for example, in [26] it has been determined that the addition of alcohols (methanol, ethanol, propanol from 5% to 20%) could decrease the NO_x until to 60%. On the contrary, the addition of oxygenated compounds affects the exhaust emission of some unregulated pollutants: this aspect can be observed for aldehydes from ethanol and organic acids formed from the additives precursors, while benzene emissions from engine can be considered as decreasing by introduction of oxygenates in the gasoline.

The potential effects arising from ethanol addition can be individuated by considering that blending gasoline and ethanol encompasses new components in the emissions [27], and in order to evaluate the potential toxicity of this qualitatively modified combustion, a complete degradation chart for oxygenated blends must be determined, starting from chemical conversion to atmospheric oxidation path. An example of this chart, from Ref. [28], is reported in Fig. 4.

As a conclusion at this point, the modification of gasoline composition very probably leads to advantages for conventional parameter emissions, to an extent that depends on many specific thermo-kinetic aspects, but careful attention must be devoted to secondary volatile pollutants arising from oxygenated precursors.

With the same approach, the objective of reduction of environmental impact from diesel fuel combustion led to many studies that consider addition of oxygenated

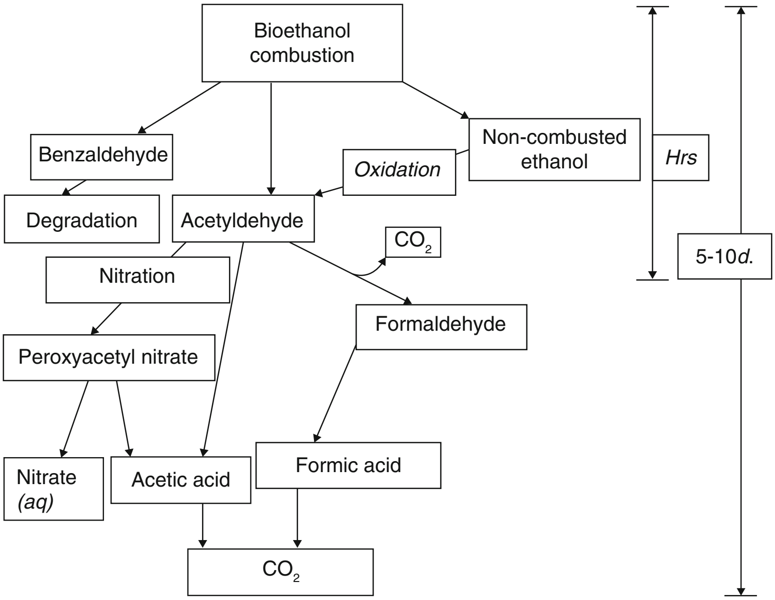

Fig. 4 Degradation charts for bioethanol – blends [28]

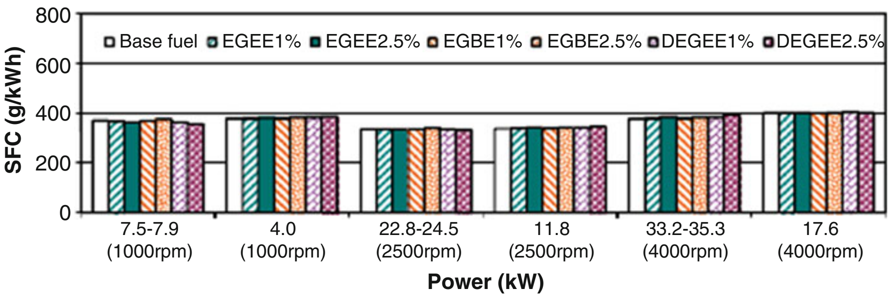

Fig. 5 Effect of EGEE, EGBE, and DEGEE addition on specific consumption [29]

compounds to diesel fuel. This addition could improve fuel combustion in engines, reducing pollutant emissions (CO, NO_x, unburned hydrocarbons, smoke) and at the same time increasing engine efficiency. Figure 5 (from Ref. [29]) is an example of the effect of the use of different glycol ethers on the principal pollutants.

3 Limitation of Climate Change

As substitution of conventional fossil fuels, biofuels are increasing their use on the market, on account of the possibility to exploit local low-cost resources but chiefly with the objective to reduce the GHG emissions. In fact, the CO_2 emission that is

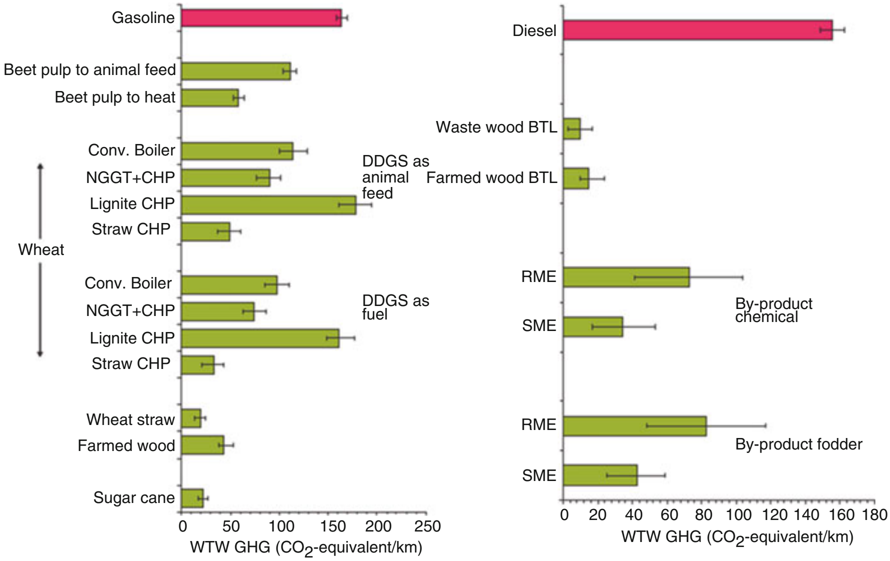

Fig. 6 Transport and environment 2007 [30]

created during the combustion is at least partially compensated from the CO_2 absorbed during the plant growth. The advantage in this sense, evaluated with a complete well-to-wheel analysis [30], by considering different biofuels, is reported in Fig. 6: the figure illustrates the total net emission of GHG needed to produce and consume enough fuel to move a vehicle for 1 km. In the figure there is also an indication of different raw materials for biofuels and different process options.

From the figure it is easy to observe a clear saving along most production pathways but also a large variation in the net saving depending on the chosen scenario.

In comparison with this clear positive effect, there are important concerns about the potential negative effects of biofuels during the growth of considered raw vegetal materials.

The rise of demand for biomass for energetic fuel production and use could put additional pressure on farmland and agricultural or forest biodiversity, and it could also affect the right use of natural resources as soil and natural water. It could very probably create negative aspects concerning waste minimization and environmentally oriented farming.

Another aspect that must be considered is the balance between the used farmland destined to biomass cultivation to support fuel production, and the use for food supply, and also the balance between biomass use for biofuels (that consumes an important quantity of energy) and biomass for bio-electricity or CHP that can be more energetically efficient.

Concerning this last point of global sustainability of a scenario of biofuels from natural materials, it is very important to consider the potential option of secondgeneration biofuels (obtained by using nonfood products and by using marginal territories); chiefly the exploitation of lignocellulosic substrates offers a very positive perspective, also if many problems of biological conversion paths and optimization of energy use must be solved.

Many studies, performed by using the LCA approach, evaluation of cost and benefits, definition of carbon footprint, and territorial best planning by using multi-criteria analysis, have been conducted concerning the possibility to extend the production of biofuels; also, obviously, the economic convenience must be considered, chiefly on account of the original territorial area where the original raw vegetal material is produced.

4 Improving the Vehicles' Energy Efficiency and Sustainability Through the Application of a Multifunctional Additive to Motor Fuels

By analyzing the data on physical and chemical processes in internal combustion engines, catalytic properties of substances, and tribological data, the formula of the multifunctional additive was theoretically proved, and the technology of its synthesis was developed [12–14, 21, 22].

An introduction of the multifunctional additive to traditional fuel in very small amounts (9.25 ppm for gasoline and 27.75 ppm for diesel fuel) provides a comprehensive positive impact on the properties of the fuel and also on the engine performance through a combination of a high surface activity of oil-soluble compound and the catalytic activity of the element in its composition.

Modifying of motor fuels being used by introduction of the developed fuel additive significantly improves energy efficiency and environmental performance of vehicles, and that is confirmed by the results of laboratory, bench, and road tests [21].

The additive is introduced in motor fuels in a controlled ultra-low concentration. Subsequent treatment of the engine by this author's technology, after decomposition of the additive in flame provides coating of the surfaces of internal combustion engine (ICE) by a catalytically active, in the gasification reactions, layer of metal in the nanocrystalline state, providing engine cleanliness. The formation of the nanolayer was confirmed by electron microscopic studies [31, 32].

Tests have shown that formation of the catalytic nanolayer in the internal combustion engines provides reduced emissions of soot precursors – polycyclic aromatic hydrocarbons, including benzo(a)pyrene by 95% (Fig. 7) – and eliminates carbon deposits itself, thus decreasing emissions of gaseous toxic substances (by 20–35%) and greenhouse gases.

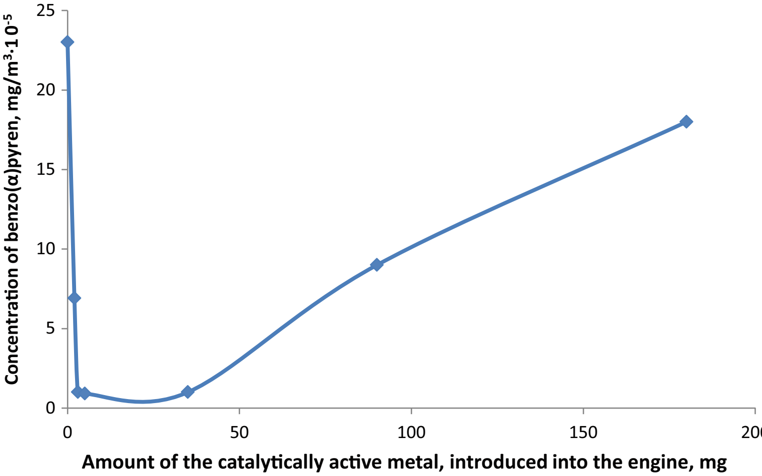

Fig. 7 The influence of modification of the gasoline by introducing the multifunctional additive on the presence of benzo(a)pyrene in the exhaust gases

Elimination of carbonization in the engine mitigates the temperature regime; this reduces the specific fuel consumption by 7–12% (Fig. 8) and the gasoline engines' requirements for the octane number of gasoline being used by up to 10 points [33].

Considering the annual motor fuel consumption, the obligatory application of fuels, modified by the additive introduction, should provide very significant economic and environmental effects and also reduces the requirements of the vehicle fleet for the high-octane gasolines.

A catalytic layer is cladding the engine surfaces, which reduces wear on the cylinder-piston group, and possesses a high corrosion resistance. Removal of soot from spark plugs of gasoline engines increases their lifetime.

It was established that even a single introduction of the additive within the fuel into the engine, followed by forming a catalytic layer on the working surfaces, leads to significant improvements in environmental and operational performance of gasoline engines. The catalytic layer retains its activity for a long enough time.

The constant use of the fuels, modified by the additive application, provides additional positive effects, improving detergent, lubricating properties, and reducing evaporation losses of gasoline [34]. It should be noted that atomic absorption analysis revealed that these modified fuels do not produce any additional toxic components in exhaust gases, in comparison with fuels before the additive application.

Considering the low cost of the proposed method to improve the energy efficiency and environmental performance of vehicles through using the motor fuels modified by the additive application, it is a prospect way both for developed and developing countries to solve the urgent task of rational use of fossil fuels and to reduce the transport negative impact on the environment.

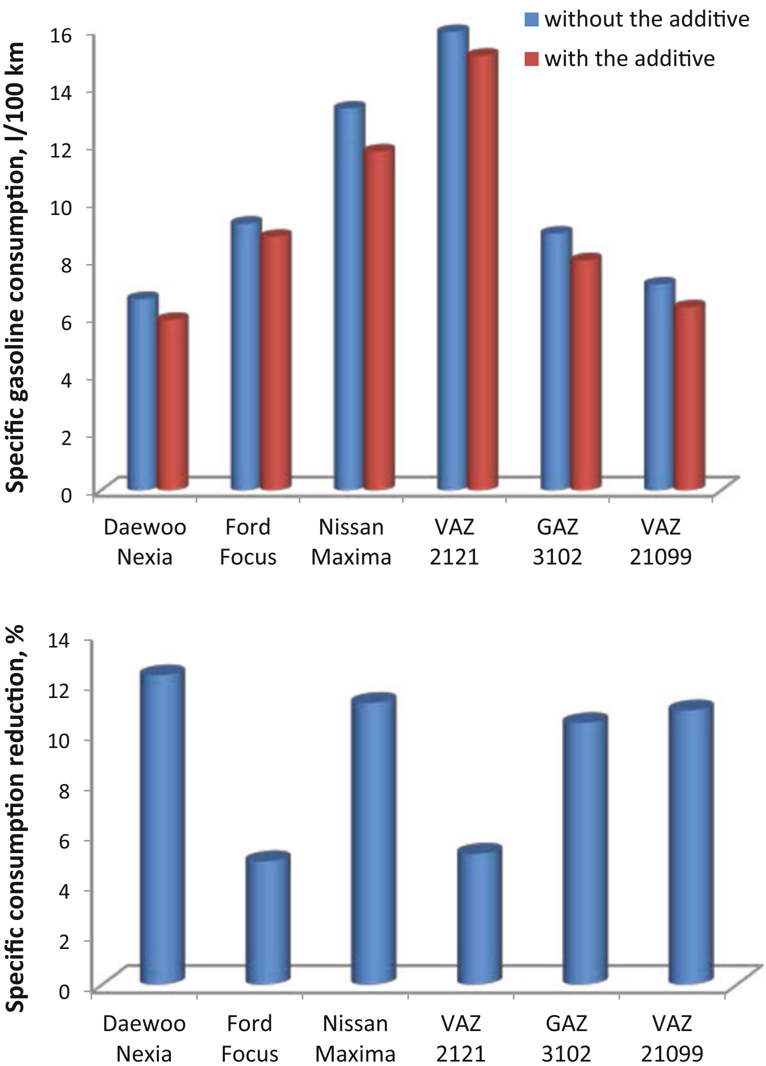

Fig. 8 The influence of gasoline modification by introducing the additive on its specific consumption

5 Conclusion

In order to improve the sustainability of road transport and automotive exploitation, there are some well-consolidated possibilities, chiefly corresponding to improvement in technological car devices, and some probably more performing but also more difficult to be adopted strategies, such as modification in mobility systems or territorial best planning. Besides these strategies, a careful consideration of the quality of fuels must be taken into account: some benefits from this could be produced concerning air quality arising from exhaust emissions, and chiefly important limitations in GHG emissions could be obtained. It is in any case very important to take into account all the aspects of fuel reformulation, with a global perspective, in order to balance the well identified advantages and to balance them in comparison with secondary pollution, territorial, and also social aspects of critical applicability.

An efficient method for improvement of energy efficiency and environmental safety of transport operation by application of the fuel additive is developed. Usage of the motor fuels, modified by introducing the additive, with minimal expenditure significantly improves the efficiency of vehicle operation, the engine state, and environmental characteristics.

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