

The Acceptable Alternative Vehicle Fuel Price

Antonina Kalinichenko ^{1,*}, Valerii Havrysh ² and Igor Atamanyuk ³

¹ Institute of Technical Science, University of Opole, 45-040 Opole, Poland

² Department of Tractors and Agricultural Machines, Operating and Maintenance, Mykolayiv National Agrarian University, 54020 Mykolayiv, Ukraine; havryshvi@mnau.edu.ua

³ Department of higher and applied mathematics, Mykolayiv National Agrarian University, 54020 Mykolayiv, Ukraine; atamanyuk@mnau.edu.ua

* Correspondence: akalinichenko@uni.opole.pl; Tel.: +48-787-321-587

Received: 7 September 2019; Accepted: 10 October 2019; Published: 15 October 2019



Abstract: Historically, petroleum fuels have been the dominant fuel used for land transport. However, the growing need for sustainable national economics has urged us to incorporate more economical and ecological alternative vehicle fuels. The advantages and disadvantages of them complicate the decision-making process and compel us to develop adequate mathematical methods. Alternative fuel (compressed natural gas, liquefied petroleum gas, and ethanol fuel mixtures), the standard prices and their ratios were investigated. A mathematical model to determine a critical ratio between alternative and conventional fuel prices had already been developed. The results of this were investigated. The results showed that the critical ratio is not a linear function on annual conventional fuel consumption costs. According to our simulation gaseous fuels were economically more attractive. Whereas, the use of bioethanol blends had more risk.

Keywords: alternative fuel; conventional fuel; investment; lifetime; efficiency; mathematical model

1. Introduction

Energy is a key element in sustaining the social and economic development of society. Energy use is the basis of the quality of life and the driver for its enhancement [1]. The combustion of fossil fuels results in the release of harmful emissions into the atmosphere. It will lead to an inevitable increase in the concentration of carbon dioxide, greenhouse gases, and other toxic compounds (nitrogen oxides, carbon monoxide, sulfur oxide, non-methane organic gas, soot, etc.) which are hazardous to human health [2,3]. Therefore, the usage of hydrocarbon energy resources negatively effects climate change [4].

Improvements in living standard have resulted in an increase of fossil fuel consumption, especially in transportation [5,6]. That is why they are currently playing a dominant role despite the ecological effects [4]. Petroleum fuels are still dominant for all kinds of transport (air, marine, and land) because of their relatively high economic efficiency. Reserves of crude oil (feedstock for the conventional fuel production) are limited and exhaustible, and there has been a rise in the world crude oil price.

A total of 22% of global air pollution comes from transportation [7]. It has been proven that there is a relationship between energy consumption, harmful emission, and economic growth [8]. Ecological issues may slow down economic growth [9].

To improve the current situation in the energy sector and ecology, 195 countries in 2015 agreed to targets directed at reducing greenhouse gas emissions [10–12]. The increase in the price of crude oil, an increase in the demand for energy resources, and harmful emission has forced us to develop alternative fuels that can both reduce harmful emission and strengthen national energy security [5,13]. Therefore, the utilization of alternative fuels, including renewable ones, is relevant. Their usage has a lot of benefits: a reduction in greenhouse emissions; the diversification of energy resources; an increase in energy security; the creation of new jobs; and the development of business [14,15].

Therefore, sustainable economic development of our civilization requires energy saving technologies, logistics optimization, alternative energy resources and fuels. Some alternative technologies are capable of delivering a sustainable land transport system: the battery electric vehicle (BEV); the hydrogen fuel cell electric vehicle (FCEV); biofuels; and gaseous fuels. Electricity and hydrogen can be produced from renewable energy or nuclear energy. In this case BEV and FCEV are transport systems with zero-carbon emissions. However, since the focus of this study is internal combustion engine vehicles, electric vehicles are not considered.

Alternative fuels may be both renewable and nonrenewable. Liquid and gaseous biofuels (ethanol, biodiesel, biogas, etc.) positively influence sustainable economic growth [16]. Nonrenewable alternative fuels (compressed natural gas, liquefied petroleum gas, etc.) improve economical, environmental, and social areas of a sustainable economy [17]. There are various drawbacks to the use of alternative fuels: technical, infrastructural, and economic. In choosing an alternative fuel, the price is the most important criteria in addition to user acceptance, reducing hazardous substances, improvement of life quality, vehicle life, etc. [18].

Consumers should have a simple method to evaluate the attractiveness of a certain vehicle fuel. The decision should be made easily based on the absolute value of the prices of different types of fuels. To predict the optimal vehicle fuel simulation models have been developed. The simulation took into account the fuel price differentials (difference between the prices of conventional and of alternative fuels) [19]. The fuel price differentials and the ratio of fuel prices were used in a number of studies [20–22]. However, the fuel price differential is an absolute value. This indicator cannot identify the optimal fuel because it depends on absolute prices. The alternative/conventional fuel price ratio is a relative indicator and gives more reliable information about preferable fuel. Abundant research discussions on alternative vehicle fuels have applied an alternative to conventional fuel price ratio: the LPG to gasoline price ratio was used to analyze the LPG market in Poland [23]; the same indicator was used for techno-economic Analysis of Liquid Petroleum Gas Fueled Vehicles for Public Transportation in Indonesia [24]; the compressed natural gas (CNG)/petroleum and LPG/diesel price ratios were used to study the development of natural gas vehicles in China [25] and to study sustainability between CNG vehicle innovative ecosystem and other vehicle innovative ecosystem [26]; the ratio of ethanol and gasoline prices was used as an indicator of ethanol blending economics [27–30]; the LNG/HFO price ratio was used to study low emission engine technologies for future legislation [31]; and the biodiesel to petroleum diesel fuel price ratio was used to study the efficiency of biodiesel utilization [32]. However, to make an optimal decision, it is necessary to take into account a number of factors: lifetime of the vehicle, fuel prices, fuel properties, investment costs, salvage income, etc. Therefore, consumers need a model that takes the above factors into account.

The aim of this study was to give information to decision-makers in order to utilize alternative fuels. The alternative fuel economics are complicated and require a sophisticated mathematical model for an analysis. To obtain this, a new mathematical model was developed to determine a maximum relative alternative fuel price when its application is feasible. The model is based on the following: a conventional fuel price, the investment costs, the discount rate, fuel properties, annual conventional fuel consumption, share of conventional fuel in dual fuel mode, and total lifetime of investment project.

2. Materials and Methods

The methodological basis of the study was relevant literature, information resources, and statistical data. Economic and mathematical modeling was employed to determine the effectiveness of fuels used.

Most land transport vehicles are designed to be operated on petroleum derived fuels (gasoline and diesel fuel). Conventional fuels are fuels derived from petroleum. Alternative fuels are not petroleum fuels and can be produced from fossil energy resources (compressed natural gas, liquefied natural gas, liquefied petroleum gas, etc.) or biomass [33]. In practice, both pure and blended biofuels are used. Compressed natural gas competes with petroleum fuels in the vehicle fuel market and it is expected to be a growing vehicle fuel in the world in the next decade [34]. The classification of

fuels was considered in previous investigations [35,36]. Alternative vehicle fuels can be divided into renewable and nonrenewable ones (Figure 1).

The main physical and chemical properties of biofuels and conventional petroleum fuels are different. Hydrotreated vegetable oil is an exception [37]. This fact complicates their utilization and compels us to use blended fuels which contain both petroleum and non-petroleum components. It makes alternative fuel properties closer to conventional fuels. Diesel fuel and pure plant oils; diesel fuel and vegetable oil methyl esters; gasoline and bioethanol are popular blends.

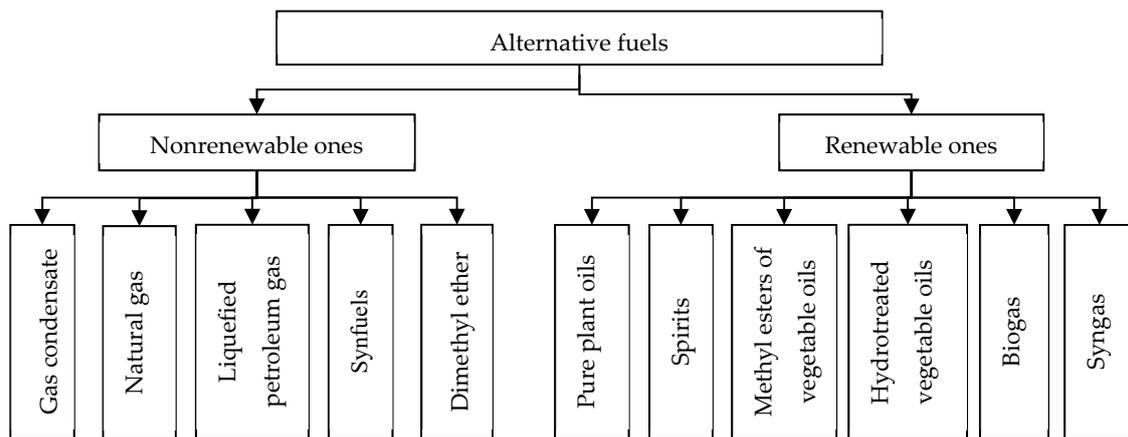


Figure 1. Classification of alternative vehicle fuels.

The determination of alternative vehicle fuel economic viability, Net Present Value (NPV), and Profitability Index (PI) analysis were applied. The mathematical model includes the following variables: Alternative and conventional fuel prices; Investment costs; Remaining salvage value; Operating lifetime; Discount rate; Ecological charges, etc.

In the study retail prices for each fuel were used. Major alternative fuels currently in widespread use (liquefied petroleum gas or propane, natural gas, biomethane, biodiesel blends, bioethanol blends, and a special kind of energy—electricity) were analyzed.

Hydrogen fuel cell vehicles have been demonstrated in Australia, Canada, China, the European Union, Japan, the USA, etc. However, the drawback of the above projects was high capital costs and the lack of hydrogen delivery infrastructure. It resulted in termination of some programs [38]. Therefore, this technology is currently developing but still not widespread. That is why hydrogen was not considered in this paper.

In the study research such indicators as energy cost, ratio of fuel prices, etc., have been used. In order to make a decision on the use of a certain fuel, it is necessary to know the energy cost (EC). It can be determined as follows [14]:

$$EC = \frac{Fpr}{Q \cdot \rho}, \text{ EUR/GJ}, \quad (1)$$

where Fpr is the fuel price, EUR/m³; Q is the lower heating value of the fuel, MJ/kg; ρ is the fuel density, t/m³.

Energy cost of blended fuels is calculated as follows [14]:

$$EC = \frac{\sum_{i=1}^n (Fpr_i \cdot c_i)}{\sum_{i=1}^n (Q_i \cdot \rho_i \cdot c_i)}, \text{ EUR/GJ}, \quad (2)$$

where Fpr_i is the price of the i^{th} component of fuel, EUR/m³; Q_i is the lower heating value of the i^{th} component of fuel, MJ/kg; ρ_i is the density of the i^{th} component of fuel, t/m³; n is the number of components; c_i is the volume fraction of the i^{th} component of fuel.

The efficiency of an internal combustion engine depends on a number of factors, including the type of fuel used. Therefore, the energy cost for useful work (ECU) is equal to [14]

$$ECU = \frac{EC}{\eta} = \frac{\sum_{i=1}^n (Fpr_i \cdot c_i)}{\eta \cdot \sum_{i=1}^n (Q_i \cdot \rho_i \cdot c_i)}, \text{ EUR/GJ}, \quad (3)$$

where η is the efficiency of an engine.

We examined the ratio of alternative fuel and conventional fuel prices as an indicator of alternative fuel economics. We also assumed that alternative fuel prices do not need to be adjusted to their lower heating value (petroleum gasoline and diesel fuel have different lower heating values).

Penetration of alternative fuels and alternative fuel vehicles depends on the fuel retail infrastructure and the price of vehicles that can use these fuels [39]. Therefore, investment costs of fueling stations and conversion kit costs were taken into account. In the study the following countries were selected:

- The USA is the world biggest consumer of alternative vehicle fuels, including renewable ones;
- Germany and Sweden hold leading positions in renewable fuels consumption (biofuels and biomethane);
- Ukraine has a large CNG and LPG fleet.

3. Results

3.1. Modeling Procedure

Fuel price differentials depend on the absolute value of conventional fuel prices. The linear correlation coefficient r measures the strength of the linear relationship between two variables: price differentials and conventional fuel prices (Figures 2 and 3). The linear correlation coefficients were calculated by authors:

- the differential between gasoline and E85 prices in the USA is equal to 0.81;
- the differential between gasoline and LPG prices in Ukraine is equal to 0.84.

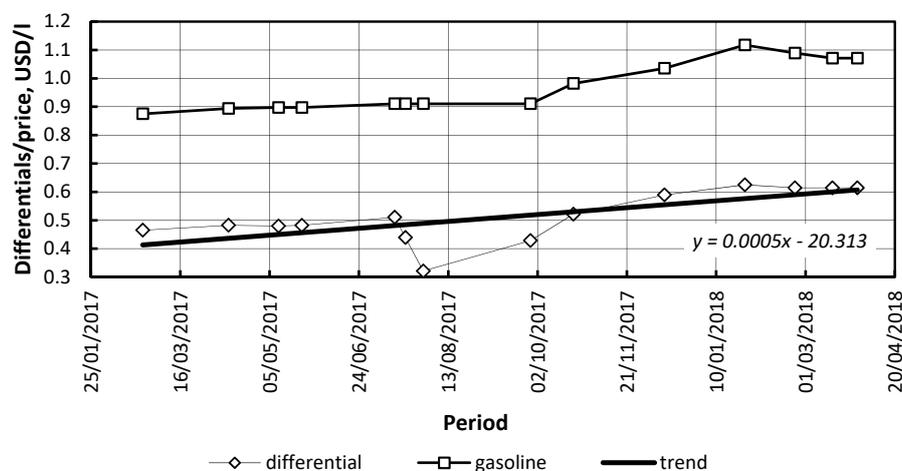


Figure 2. Fuel price differentials (the difference between gasoline and LPG prices) in Ukraine.

The above means that there is strong correlation between price differentials and conventional fuel prices. Therefore, it is reasonable to use a ratio between alternative and conventional fuel prices.

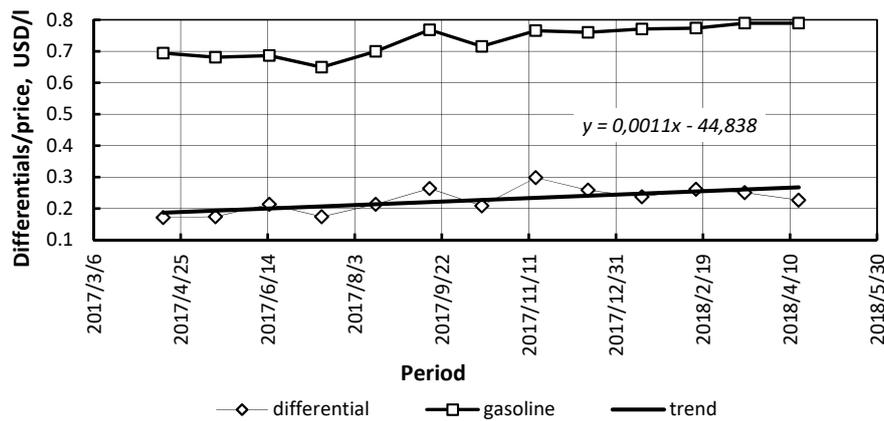


Figure 3. Fuel price differentials (the difference between gasoline and E85 prices) in the USA.

If $ACFC$ is the annual costs of conventional fuel and $AAFC$ is the annual costs of alternative fuel, the return of alternative fuel utilization can be found as their difference

$$R = ACFC - AAFC = \frac{M}{\rho} \cdot DFpr + EC_C - \left[\varphi \cdot DFpr \cdot \frac{M}{\rho} + (1 - \varphi) \cdot M \cdot \frac{Q \cdot AFpr \cdot \eta_C}{Q_A \cdot \rho_A \cdot \eta_A} + EC_A \right], \quad (4)$$

where M is the annual consumption of conventional fuel, t; $DFpr$ is the price of conventional fuel, EUR/L; ρ is the density of conventional fuel, kg/L; ρ_A is the density of alternative fuel, kg/L; EC_C is the annual ecological charges for the conventional fuel, EUR; EC_A is the annual ecological charges for the alternative fuel, EUR; $AFpr$ is the price of the alternative fuel, EUR/L; φ is the conventional fuel energy share in fuel blends or for a dual fuel mode; Q is the lower heating value of the conventional fuel, MJ/kg; Q_A is the lower heating value of the alternative fuel, MJ/kg; η_C is the efficiency of vehicle which runs on the conventional fuel; η_A is the efficiency of vehicle which runs on the alternative fuel.

Alternative fuel vehicles can use single and multiple fuel sources. Dual fuel vehicles use two types of fuel at the same time with a different fuel tank, for example, CNG and diesel fuel. The share of conventional fuel in fuel blends (φ) ranges from 0 to 1.

After transformation, the above equation will have the form

$$R = (1 - \varphi) \cdot \frac{M}{\rho} \cdot DFpr \cdot \left[1 - \frac{Q \cdot \rho \cdot AFpr \cdot \eta_C}{Q_A \cdot \rho_A \cdot DFpr \cdot \eta_A} \right] + EC_C - EC_A. \quad (5)$$

Denoted by γ the ratio of alternative fuel price to conventional fuel price $\gamma = AFpr/DFpr$, then the Equation (5) will have the following form

$$R = (1 - \varphi) \cdot \frac{M}{\rho} \cdot DFpr \cdot \left[1 - \gamma \cdot \frac{Q \cdot \rho \cdot \eta_C}{Q_A \cdot \rho_A \cdot \eta_A} \right] + EC_C - EC_A. \quad (6)$$

For electric vehicles, a mathematical expression for return is different. Annual consumption of electricity by vehicle is equal to

$$W = \frac{M \cdot Q \cdot \eta_C}{3.6 \cdot \eta_E}, \text{ kWh}, \quad (7)$$

where η_E is the efficiency of vehicle which runs on electricity.

Then, return for electric vehicles is determined as following

$$R_E = \frac{M}{\rho} \cdot DFpr + EC_C - [W \cdot EEpr + EC_E], \quad (8)$$

where $EEpr$ is the price of electricity, EUR/kWh; EC_E is the annual ecological charges for electricity.

After transformation, the return for electric vehicles utilization is

$$R_E = \frac{M}{\rho} \cdot DFpr - \frac{M \cdot Q \cdot \eta_C}{3.6 \cdot \eta_E} \cdot EEpr + EC_C - EC_E, \text{ EUR.} \quad (9)$$

Net Present Value (*NPV*) and Profitability Index (*PI*) were considered as criteria for investment projects. If *NPV* is a criterion of an investment project, then for a regular cash flow its value is

$$NPV = R \cdot \frac{1 - (1 + g)^{-n}}{g} - I, \quad (10)$$

where *g* is the discount rate; *I* is the investment costs, EUR; *n* is the lifetime of a certain investment project, year.

For consumers, it is important to know a break-even point of a certain alternative fuel project. In this point total costs and revenue are equal. It means that the Net Present Value is equal to zero. A critical value on the return can be found from an equation

$$NPV^* = R^* \cdot \frac{1 - (1 + g)^{-n}}{g} - I = 0, \quad (11)$$

where R^* is the critical value of the return, EUR.

From the above equation the critical value of the return is equal to

$$R^* = I \cdot \frac{g}{1 - (1 + g)^{-n}}. \quad (12)$$

It should be equated with the right parts of Equations (6) and (12)

$$R^* = (1 - \varphi) \cdot \frac{M}{\rho} \cdot DFpr \cdot \left[1 - \gamma^* \cdot \frac{Q \cdot \rho}{Q_A \cdot \rho_A} \right] + EC_C - EC_A = I \cdot \frac{g}{1 - (1 + g)^{-n}}, \quad (13)$$

where γ^* is the critical value of the relative price for the alternative fuel.

Further

$$(1 - \varphi) \cdot \frac{M}{\rho} \cdot DFpr \cdot \left[1 - \gamma^* \cdot \frac{Q \cdot \rho}{Q_A \cdot \rho_A} \right] = I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A). \quad (14)$$

The critical value of γ^* can be found from Equation (14). Therefore

$$\gamma^* = \frac{Q_A \cdot \rho_A}{Q \cdot \rho} \cdot \left[1 - \left\{ I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A) \right\} \cdot \frac{1}{(1 - \varphi) \cdot \frac{M \cdot DFpr}{\rho}} \right]. \quad (15)$$

Denoted by *ACFC* the annual conventional fuel consumption cost

$$ACFC = \frac{M \cdot DFpr}{\rho}. \quad (16)$$

Then Equation (15) takes the form

$$\gamma^* = \frac{Q_A \cdot \rho_A}{Q \cdot \rho} \cdot \left[1 - \left\{ I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A) \right\} \cdot \frac{1}{(1 - \varphi) \cdot ACFC} \right]. \quad (17)$$

From the above equation the critical ratio of fuel prices can be found. If actual ratio of fuel prices γ is less than the critical one γ^* , then an investment project is expedient. The above ratio can be used

for the sensitive analysis procedure of investment projects [40–42]. Let us explore the above function in Equation (15).

If $DF_{pf} = 0$, then $\gamma^* = -\infty$. It means that the alternative fuel price must be less than 0. This statement does not make sense (Figure 4).

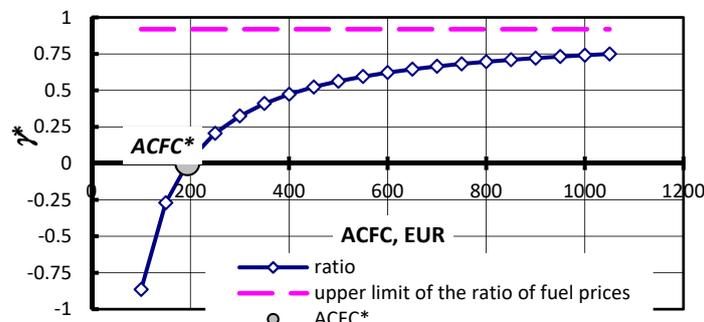


Figure 4. The dependence on the ratio of alternative fuel price to conventional fuel price on the annual conventional fuel consumption cost (criterion—NPV).

If $DF_{pf} = \infty$, then $\gamma^* \rightarrow Q_A \cdot \rho_A \cdot Q^{-1} \cdot \rho^{-1}$.

Let us find a critical value of the annual conventional fuel consumption cost $ACFC^*$ from Equation (14)

$$1 - \left\{ I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A) \right\} \cdot \frac{1}{(1 - \varphi) \cdot ACFC^*} = 0. \tag{18}$$

Therefore

$$1 = \left\{ I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A) \right\} \cdot \frac{1}{(1 - \varphi) \cdot ACFC^*}. \tag{19}$$

Therefore, the cost of the conventional fuel cost consumed is equal to (Figure 4)

$$ACFC^* = \left\{ I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A) \right\} \cdot \frac{1}{(1 - \varphi)}. \tag{20}$$

To ensure the sustainable development of any organization, the profitability index of the investment project must be at least 1.2. If the profitability index is used as a criterion on an investment project, the critical value of the return will be

$$R^* = 1.2 \cdot I \cdot \frac{g}{1 - (1 + g)^{-n}}. \tag{21}$$

In this case critical value of γ^* can be found from an equation

$$R^* = (1 - \varphi) \cdot ACFC \cdot \left[1 - \gamma^* \cdot \frac{Q \cdot \rho}{Q_A \cdot \rho_A} \right] + EC_C - EC_A = 1.2 \cdot I \cdot \frac{g}{1 - (1 + g)^{-n}}. \tag{22}$$

Then

$$(1 - \varphi) \cdot ACFC \cdot \left[1 - \gamma^* \cdot \frac{Q \cdot \rho}{Q_A \cdot \rho_A} \right] = 1.2 \cdot I \cdot \frac{g}{1 - (1 + g)^{-n}} - (EC_C - EC_A). \tag{23}$$

From the Equation (23) the critical value of γ^* is equal to

$$\gamma^* = \frac{Q_A \cdot \rho_A}{Q \cdot \rho} \cdot \left[1 - \left\{ \frac{1.2 \cdot g \cdot I}{1 - (1 + g)^{-n}} - (EC_C - EC_A) \right\} \cdot \frac{1}{(1 - \varphi) \cdot ACFC} \right]. \tag{24}$$

In this case the function obtained gives the result which is somewhat less than a function according to Equation (14) (Figure 5).

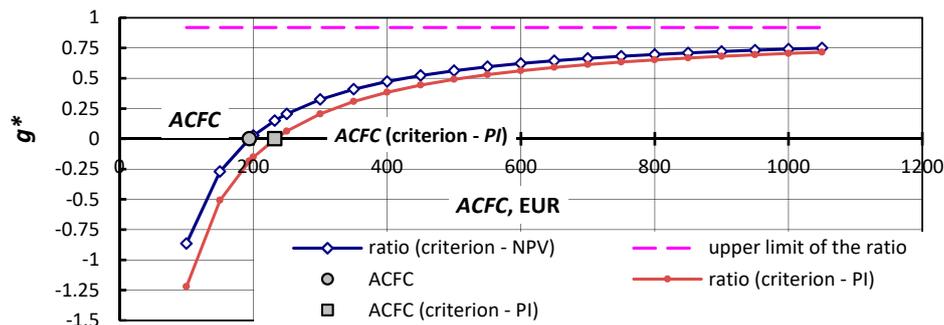


Figure 5. The dependence of the ratio of alternative fuel price to conventional fuel price on the annual conventional fuel consumption cost (criterion—PI).

3.2. Initial Data for Modeling

To evaluate the efficiency of an alternative fuel vehicle compared to a conventional one, initial data should be found. The most important initial information is lifetime, fuel prices, fuel properties, discount rate, investment costs, salvage income, etc.

3.2.1. Lifetime of a Project

Firstly, tractors were considered. The lifetime of any project cannot exceed the economic life for a certain agricultural tractor. The economic life (EL) is a function of a service life and average annual utilization.

$$EL = \frac{SL}{AAU}, \text{ years}, \quad (25)$$

where SL is the service life, h; AAU is the average annual utilization, h/year.

For agricultural tractors a service life is around 10,000–12,000 h [43,44]. According to the recommendation of experts, the economic life must not exceed 15 years [45,46].

As for automobiles, there has been an increase in the average vehicle lifetime. According to statistical data, the expected median lifetime is, in years: car—16.9; light truck—15.5; heavy truck—28.0 [47]. In 2016 the average age of the USA automobiles was 11.6 years. Estimated annual vehicle mileage of travel depends on the type of vehicle. It is 9721 miles for cars and 10,353 miles for light trucks [48].

3.2.2. Fuel Prices and Their Ratio

The most widespread fuels were considered: gasoline, conventional diesel fuel, compressed natural gas (CNG) (compressed biomethane), liquefied petroleum gas, biodiesel, and bioethanol blends. Our calculations (for conditions of Ukraine, the USA, and Germany) showed that the ratio of alternative/conventional fuel prices is not stable (Figures 6–11). As it can be seen, in Ukraine there was a drop in the ratio. Therefore, alternative fuels (LPG and CNG) may compete with conventional (petroleum) fuels.

The same method was applied to the fuel markets of different countries: the USA and Germany. The above ratio was determined for bioethanol blends in the USA (Figures 12 and 13), and LPG in Germany (Figure 14 and Figure 17). Figures 12–17 present the following:

- The actual alternative to conventional fuel price ratios;
- The optimal ratio of alternative/conventional fuel prices ($RCAP$) [14]

$$RCAP = \frac{\rho_A \cdot Q_A}{\rho \cdot Q}. \quad (26)$$

If the actual ratio is less than the optimal ratio then the use of the alternative fuel may be profitable.

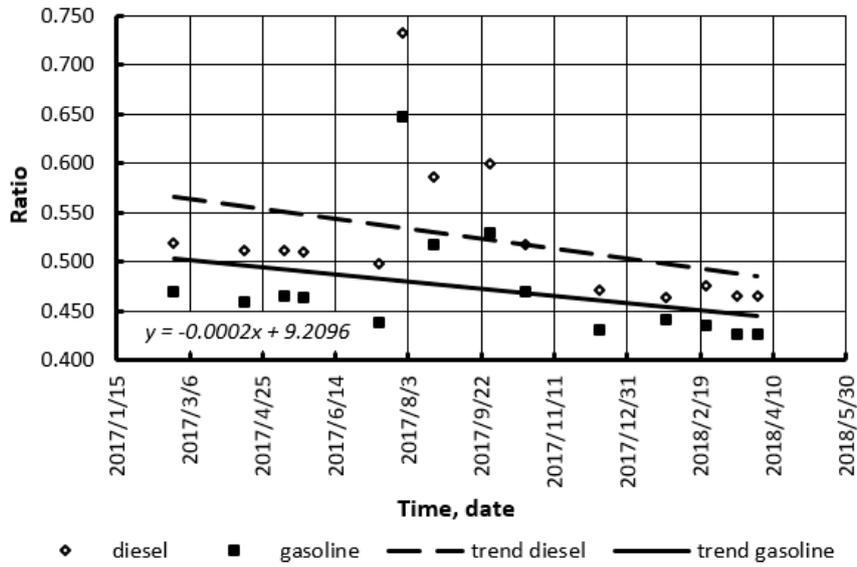


Figure 6. LPG/conventional fuel prices ratio in Ukraine.

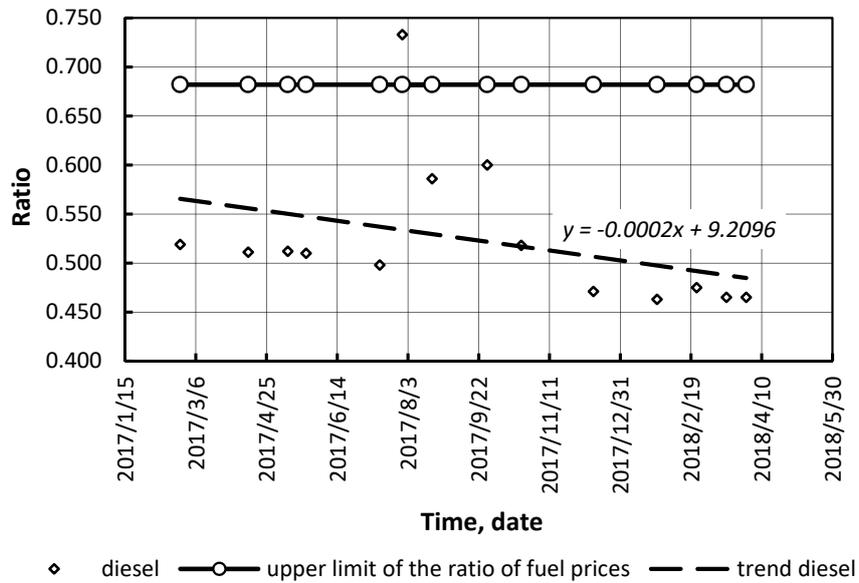


Figure 7. LPG/diesel prices ratio in Ukraine.

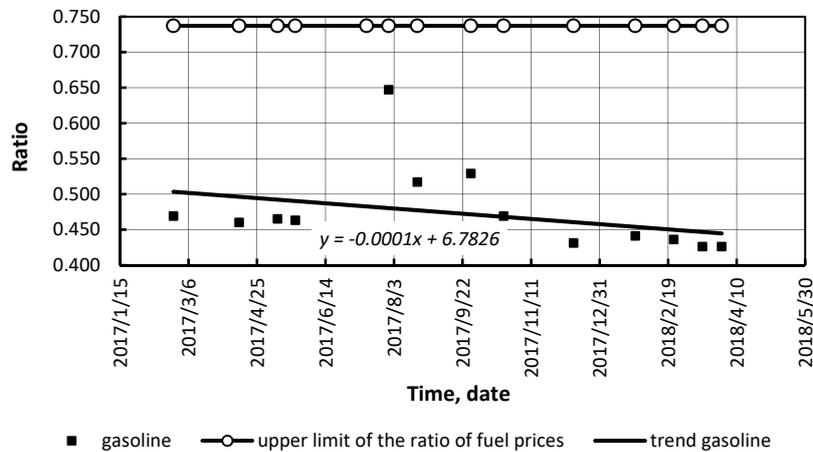


Figure 8. LPG/gasoline prices ratio in Ukraine.

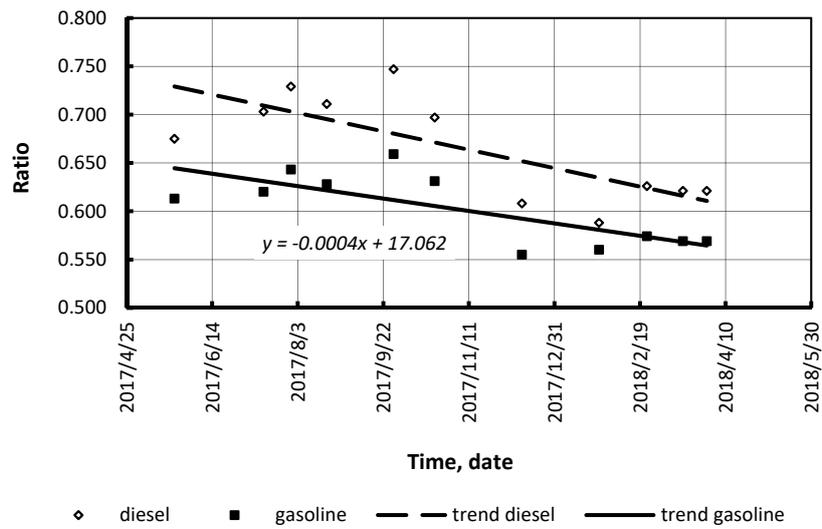


Figure 9. Compressed natural gas (CNG)/conventional fuel prices ratio in Ukraine.

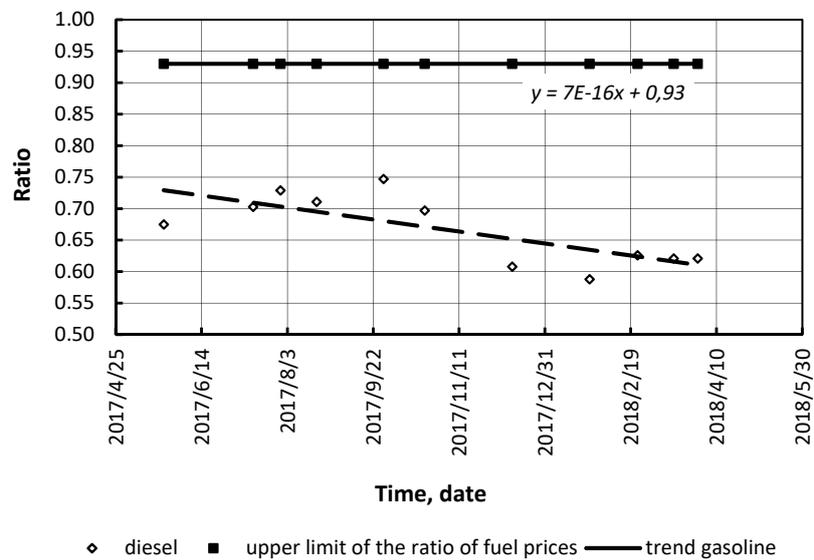


Figure 10. CNG/diesel prices ratio in Ukraine.

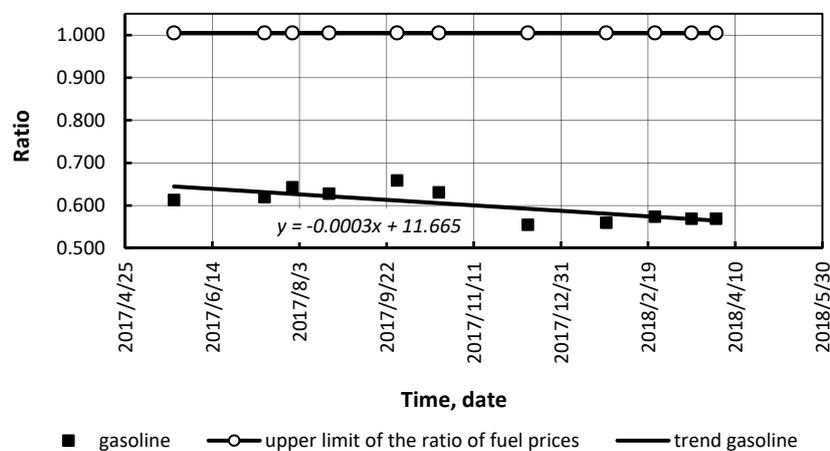


Figure 11. CNG/gasoline prices ratio in Ukraine.

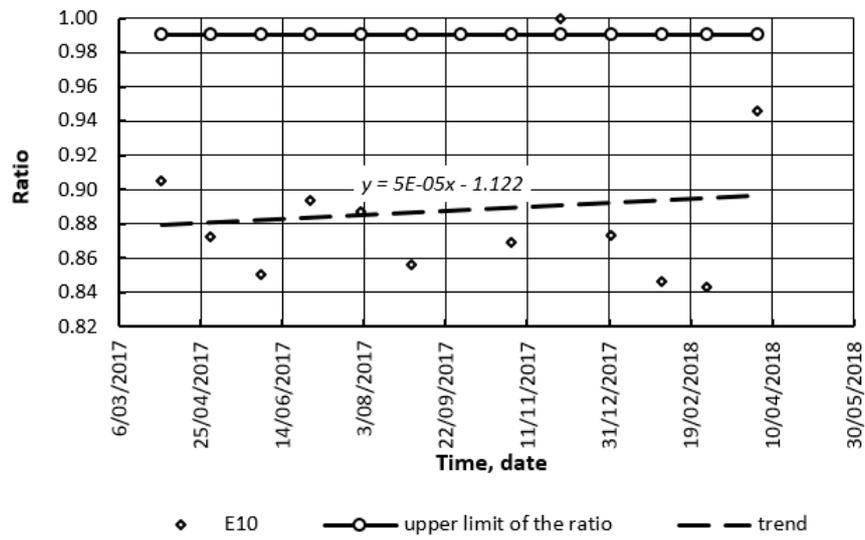


Figure 12. E10/gasoline prices ratio in the USA [49].

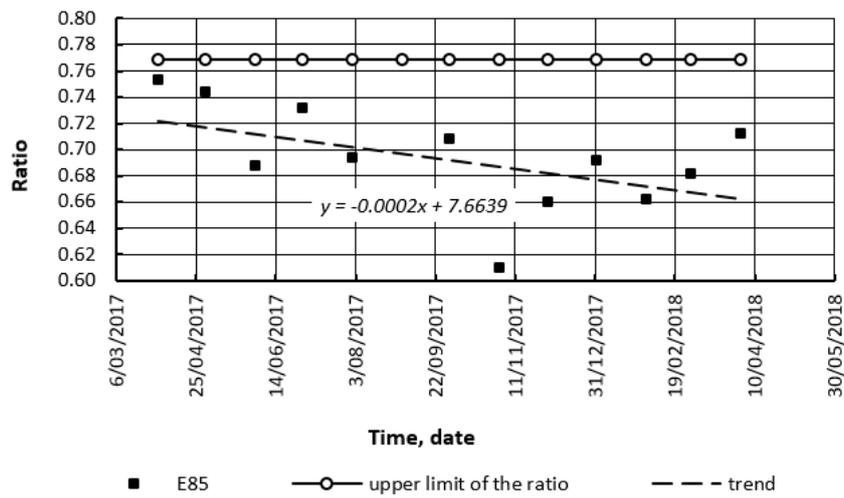


Figure 13. E85/gasoline prices ratio in the USA [49].

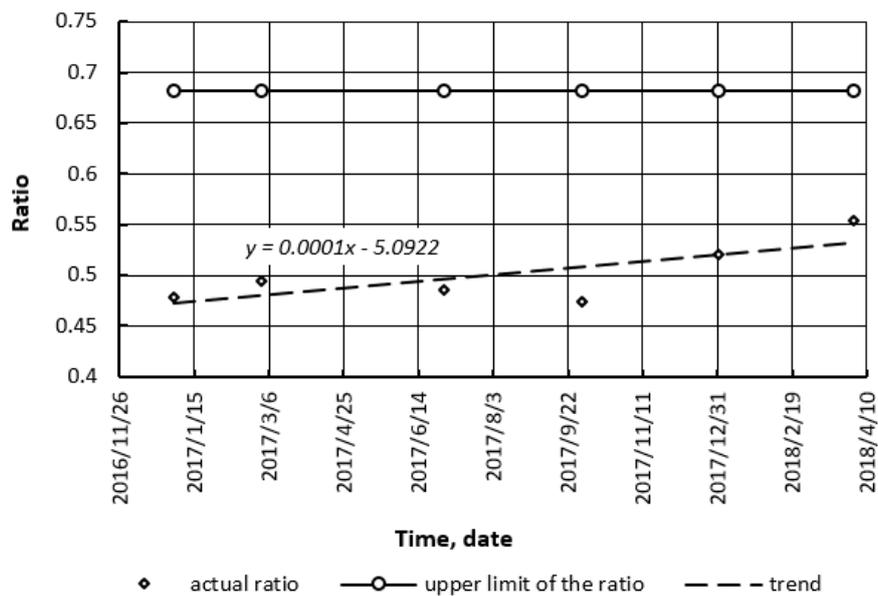


Figure 14. LPG/diesel prices ratio in Germany.

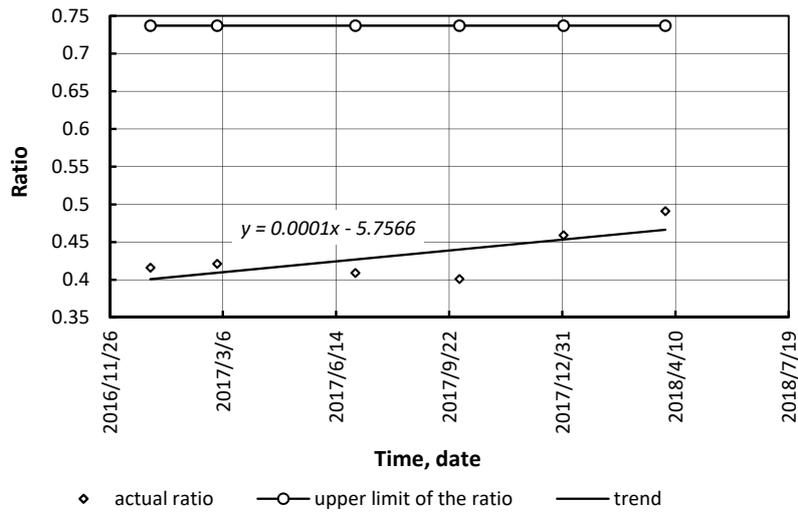


Figure 15. LPG/gasoline prices ratio in Germany.

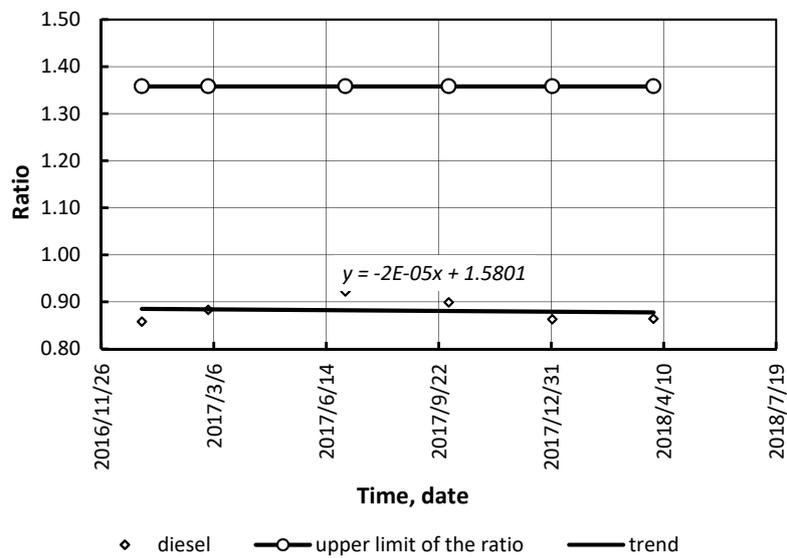


Figure 16. CNG/diesel prices ratio in Germany.

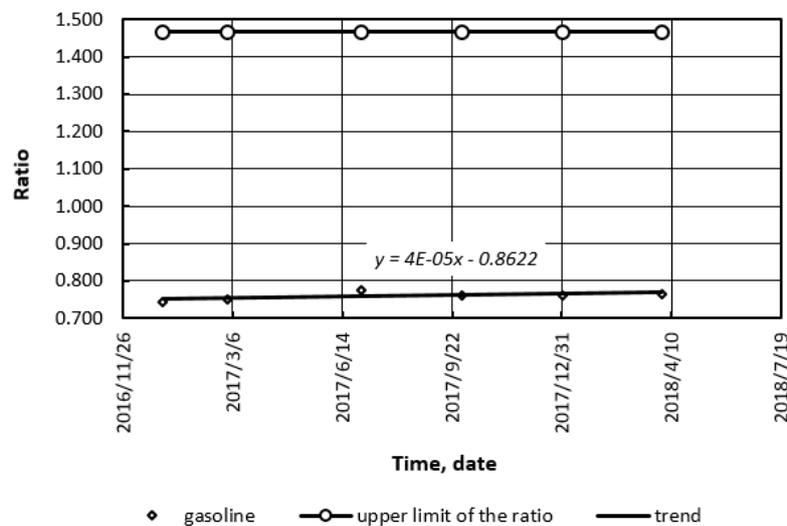


Figure 17. CNG/gasoline prices ratio in Germany.

The analysis carried out shows the following. The actual ratios for E10 fuel range from 0.84 to 1.0. These values are from 84.8% to 101% of the optimal ratio. The actual ratios for E85 fuel varied from 0.61 to 0.755. These values are 79.2%–98.7% of the optimal ratio for this alternative fuel. Therefore, the prices of E85 were more competitive than the prices of E10.

The ratios of CNG/diesel and CNG/gasoline prices in Germany are stable (Figures 16 and 17) [50,51]. Additionally, the use of LPG and CNG can guarantee profitability of transport.

For Sweden, ratios of Alternative/Conventional fuel prices are presented in Figure 18. The calculations were made using data from the website [52]. As can be seen, those alternative fuels have attractive prices. For estimation of the cost parameters in the future periods of time, forecast models can be used [53,54].

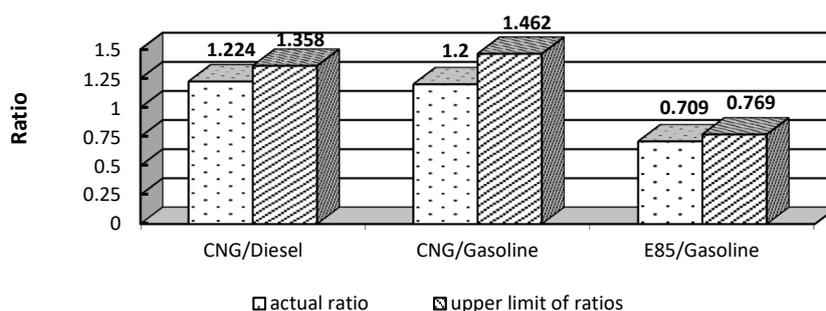


Figure 18. Ratios of Alternative/Conventional fuel prices in Sweden.

3.2.3. Investment Costs

Investment costs include two components: conversion kit price and infrastructure costs. E85 conversion kit ranges from USD139 to USD800. CNG conversion kit costs much more especially for tractor diesel engines. Its value depends on vehicle type and origin of equipment. Therefore, its cost for an agricultural tractor MTZ-1221.2 is USD1600 [55]. Omnitek Engineering, Corp develops diesel-to-natural gas engine conversion kits. For engines without turbocharger, the conversion kit may cost from USD7000 (gas tanks and installation are extra) [56].

To reduce CNG cost, a certain company can build their own CNG fueling station. Their investment costs vary from capacity (daily gaseous fuel demands) and station type (fast-fill or time-fill) (Figure 19) [57].

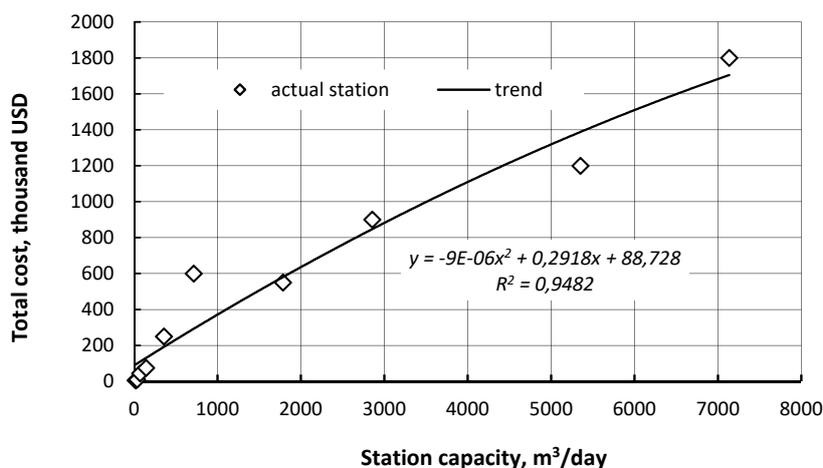


Figure 19. CNG fueling station cost [56].

3.2.4. Fuel Economy

High octane bioethanol blends enable to improve energy efficiency and, as a result, vehicle energy economy [58,59]. Fuel economy impacts on decision-making. The use of bioethanol blends changes the

fuel economy of vehicles (Table 1) [60]. The average ratio of E85 consumption per 100 km to gasoline consumption per 100 km is 1.367. According to our calculation, the coefficient of variation is 0.0458. If the above ratio is lower than ratio between gasoline price and E85 price, then the alternative fuel is appropriate.

From September 2017, in the USA E85 is economically justified. From April 2017 to April 2018 in the USA the average ratio gasoline price/E85 price is 1.45 (Figure 13). In March 2018 in Sweden the above ratio ranges from 1.42 to 1.466 [52].

The dual-fuel mode engine (diesel fuel and CNG) population is rising in the world. They have better ecological features and energetic performance. Their efficiency depends on load and speed. They are more economical on the conventional diesel mode with lower loads. The increase of load results in an improvement in dual-fuel mode engine efficiency [61]. The effective efficiency increases when a diesel engine is fueled with LPG too. For compressed ignition engines, the substitute ratio of diesel fuel with LPG is up to 30% [62].

Table 1. Fuel economy (adapted from [59]).

Make	Fuel Economy, gal/100 miles		E85/Gasoline Ratio
	Gasoline	E85	
Ford Focus FWD FFV, Automatic (AM6)	3.2	4.3	1.344
Ford Focus FWD FFV, Manual 5-spd	3.6	4.8	1.333
Mercedes-Benz CLA250 4matic	3.7	5.15	1.392
Chrysler 200	3.7	5	1.351
Audi A5 quattro	4	5.6	1.400
Jeep Renegade 2WD	4	5.3	1.325
Chevrolet Equinox FWD	4	5.9	1.475
GMC Terrain FWD	4	5.9	1.475
Jeep Cherokee FWD	4	5.6	1.400
Audi A5 Cabriolet quattro	4.2	5.9	1.405
Ford Escape FWD FFV	4.2	5.6	1.333
Jeep Cherokee 4WD	4.3	5.9	1.372
Chevrolet Equinox AWD	4.3	5.9	1.372
Ford Transit Connect Van FFV	4.3	5.9	1.372
Chrysler 200	4.3	5.9	1.372
Dodge Charger	4.3	5.9	1.372
Audi Q5	4.5	5.2	1.156
Ford F150 Pickup 2WD FFV	4.5	6.2	1.378
Ford F150 2WD FFV BASE PAYLOAD LT TIRE	4.8	6.2	1.292
Chevrolet Silverado C15 2WD	5	7.1	1.420
GMC Sierra C15 2WD	5	7.1	1.420
Ford Explorer 2WD FFV	5	6.7	1.340
Mercedes-Benz GLE350 4matic	5.3	7.1	1.340

The energy share of diesel fuel depends on a fuel supply system and operational load. Common rail diesels have better of the above. It ranges from 5% to 17% [20,63]. If a diesel engine is fueled with an in-line high pressure pump, the energy share can be calculated as

$$\varphi = 1 - (1 - \varphi_0) \cdot \frac{P_0}{P_r}, \quad (27)$$

where P_0 is the operational power, kW; P_r is the rated power, kW; φ_0 is the energy share of diesel fuel on the rated power, $\varphi_0 = 0.25\text{--}0.3$.

4. Results of Modeling

In this section results of modeling for gaseous fuel and liquid biofuel are presented. CNG and E85 were selected as widespread fuels. CNG was examined for a dual fuel diesel engine. The results

are acceptable both for tractors and diesel-powered trucks. Biethanol blend was examined for spark ignition engine vehicles.

The Agricultural CNG-powered tractor MTZ-122.1 [54] in Ukraine was examined. A municipal fleet runs the tractors (no investment in their own CNG fueling station). Figure 20 shows the maximum acceptable values of the ratio of CNG/diesel fuel prices versus the annual diesel fuel consumption costs for two types of fuel systems: an in-line high-pressure fuel pump and a common rail system. The actual ratios of the studied fuels are also shown here: the upper value and the lower value (actual market price ratios).

According to our calculations, CNG-powered tractor utilization is feasible if annual conventional fuel (diesel fuel) consumption is at least EUR9500. It corresponds to 600 h of annual utilization. If common rail is used instead of an in-line high pressure pump, the efficiency increases. To cover expenses in tractor conversion, it is enough to have EUR6200 annual conventional fuel consumption or 400 operating hours (Figure 20).

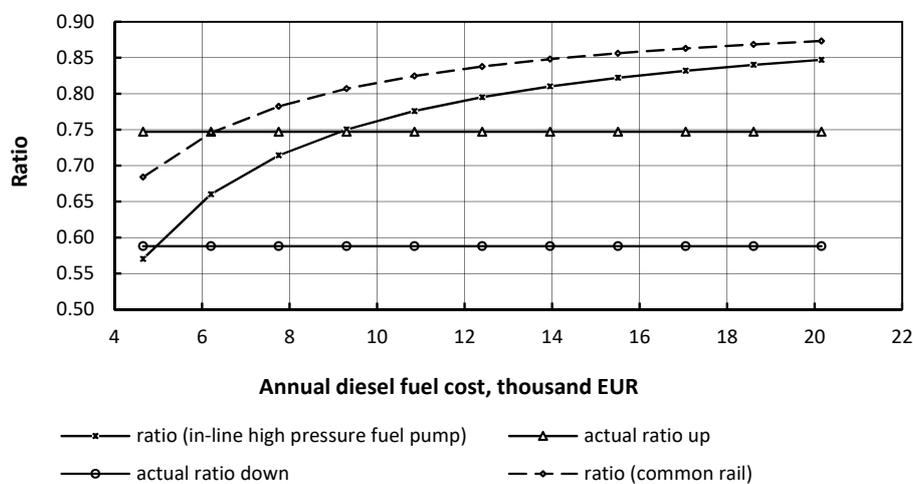


Figure 20. The dependence of the ratio of CNG/diesel fuel prices on the cost of the annual conventional fuel (no CNG fueling station).

Figure 21 shows the acceptable E85/gasoline price ratio versus annual gasoline consumption cost. The actual ratios of E85 and gasoline prices are also shown here: upper value, lower value, and average value (actual market price ratios). As can be seen, at the maximum market prices for E85, this type of fuel is not competitive. Although, the average value of its price ensures the profitability if a vehicle is used intensively.

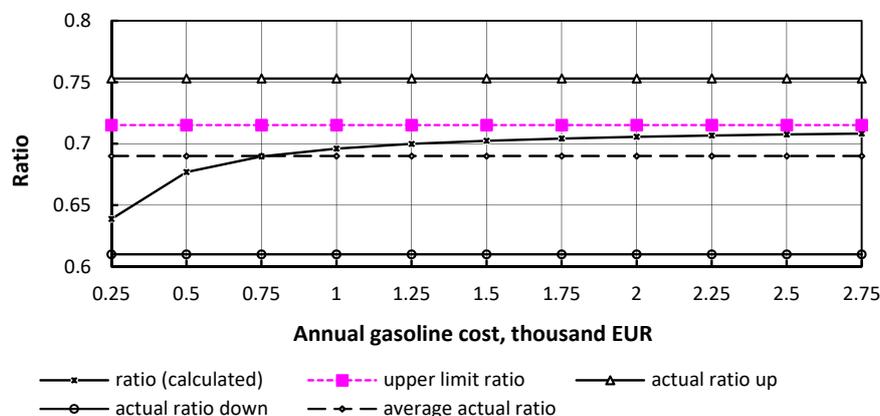


Figure 21. The dependence of the ratio of E85/gasoline prices on the annual conventional fuel cost (the USA).

The economic efficiency of an E85 vehicle is lower than CNG utilization (Figure 21). Therefore, if there are not any incentives that bioethanol blend utilization undertakes risks.

5. Conclusions

Efforts to reduce climate change and find the answer to the world crude oil crisis have resulted in the production and use of alternative vehicle fuels. In conditions of a market economy, fuel producers and consumers make decisions which depend on economic efficiency. Therefore, the price of fuel is the most important criterion.

To evaluate the feasibility of alternative fuels, a mathematical model was developed. The ratio between of alternative fuel price and conventional fuel price proved to be an optimal criterion for the model. It took into account fuel properties, vehicle performance whilst running on different fuels, and financial indicators. If the calculated ratio is higher than actual one, then the use of alternative fuel is rational.

According to calculations made, a more preferable alternative fuel is natural gas. The efficiency of its utilization depends primarily on the annual conventional fuel consumption, lifetime of a project, and the current ratio of alternative to conventional fuel prices.

Moreover, the above model may be used for the sensitivity analysis of investment projects.

Separate issues remain outside of this study. The use of electric vehicles is a multifaceted problem. In the above mathematical model cost of the infrastructure for electric vehicles (BEV and FCEV) should be incorporated. For a sustainable transport system, power generation and hydrogen production must be coupled with renewable energy sources. This should be factored in. Moreover, electric trucks and buses are starting to be produced and they must be the subject of further research.

Author Contributions: Data curation, A.K. and V.H.; Formal analysis, I.A.; Methodology, A.K. and V.H.; Project administration, A.K.; Resources, V.H. and I.A.; Writing—original draft, A.K. and V.H.; Writing—review & editing, I.A.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Nomenclature

<i>AAU</i>	the average annual utilization, h/year
<i>ACFC</i>	the annual conventional fuel consumption cost, EUR
<i>AFpr</i>	the price of the alternative fuel, EUR/L
BEV	the battery electric vehicle
c_i	the volume fraction of the i^{th} component of fuel
<i>DFpr</i>	the price of conventional fuel, EUR/L
EC_A	the annual ecological charges for the alternative fuel, EUR
EC_C	the annual ecological charges for the conventional fuel, EUR
EC_E	the annual ecological charges for electricity, EUR
<i>EEpr</i>	the price of electricity, EUR/kWh
<i>EL</i>	the economic life, year
FCEV	the hydrogen fuel cell electric vehicle
<i>Fpr</i>	the fuel price, EUR/m ³
Fpr_i	the price of the i^{th} component of fuel, EUR/m ³
<i>g</i>	the discount rate
<i>I</i>	the investment costs, EUR
<i>M</i>	the annual consumption of conventional fuel, t
<i>n</i>	the lifetime of a certain investment project, year
<i>NPV</i>	Net Present Value
P_0	the operational power, kW
P_r	the rated power, kW
<i>PI</i>	Profitability Index

Q	the lower heating value of the fuel, MJ/kg
Q_A	the lower heating value of the alternative fuel, MJ/kg
Q_i	the lower heating value of the i^{th} component of fuel, MJ/kg
R^*	the critical value of the return, EUR
SL	the service life, hours
ρ	the fuel density, t/m^3
ρ_i	the density of the i^{th} component of fuel, t/m^3
ρ_A	the density of alternative fuel, kg/L
η	the efficiency of an engine
η_A	the efficiency of vehicle which runs on the alternative fuel
η_C	the efficiency of vehicle which runs on the conventional fuel
η_E	the efficiency of vehicle which runs on electricity
φ	the conventional fuel energy share in fuel blends or for a dual fuel mode
φ_0	the energy share of diesel fuel on the rated power
γ	the ratio of alternative fuel price to conventional fuel price
γ^*	the critical value of the relative price for the alternative fuel

References

1. Yilmaz, I.; Ilbas, M. An experimental study on hydrogen–methane mixtured fuels. *Int. Commun. Heat Mass Transf.* **2008**, *35*, 178–187. [CrossRef]
2. Sinyak, Y.V.; Kolpakov, A.Y. Economic efficiency of synthetic motor fuels from natural gas. *Stud. Russ. Econ. Dev.* **2012**, *23*, 27–36. [CrossRef]
3. Rosa, R.N. The Role of Synthetic Fuels for a Carbon Neutral Economy. *J. Carbon Res.* **2017**, *3*, 11. [CrossRef]
4. Gaigalis, V.; Markevicius, A.; Skema, R.; Savickas, J. Energy strategy of Lithuanian Ignalina Nuclear Power Plant region for 2012–2035 as a chance for regional development. *Renew. Sustain. Energy Rev.* **2015**, *51*, 1680–1696. [CrossRef]
5. Lanjewar, B.P.; Rao, V.R.; Kale, V.A. Assessment of alternative fuels for transportation using a hybrid graph theory and analytic hierarchy process method. *Fuel* **2015**, *154*, 9–16. [CrossRef]
6. Speth, L.R.; Rojo, C.; Malina, R.; Barrett, R.H.S. Black carbon emissions reductions from combustion of alternative jet fuels. *Atmos. Environ.* **2015**, *105*, 37–42. [CrossRef]
7. IEA. Statistics: CO₂ Emissions from Fuel Combustion. 2017. Paris. Report. Available online: <https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustionHighlights2017.pdf> (accessed on 4 September 2018).
8. Antonakakis, N.; Chatziantoniou, I.; Filis, G. Energy consumption, CO₂ emissions, and economic growth: An ethical dilemma. *Renew. Sustain. Energy Rev.* **2017**, *68*, 808–824. [CrossRef]
9. Ozokcu, S.; Ozdemir, O. Economic growth, energy, and environmental Kuznets curve. *Renew. Sustain. Energy Rev.* **2017**, *72*, 639–647. [CrossRef]
10. Fragkos, P.; Tasios, N.; Paroussos, L.; Capros, P.; Tsani, S. Energy system impacts and policy implications of the European intended nationally determined contribution and low-carbon pathway to 2050. *Energy Policy* **2017**, *100*, 216–226. [CrossRef]
11. European Commission. Climate Action—Paris Agreement. 2015. Available online: https://ec.europa.eu/clima/policies/international/negotiations/paris_en (accessed on 15 May 2017).
12. Rogelj, J.; Elzen, M.; Höhne, N.; Franssen, T.; Fekete, H.; Winkler, H.; Schaeffer, R.; Sha, F.; Riahi, K.; Meinshausen, M. Paris agreement climate proposals need a boost to keep warming well below 2 °C. *Nature* **2016**, *534*, 631–639. [CrossRef]
13. Rahman, A.; Rasul, G.M.; Khan, M.M.M.; Sharma, S. Recent development on the uses of alternative fuels in cement manufacturing process. *Fuel* **2015**, *145*, 84–99. [CrossRef]
14. Goncharuk, A.G.; Havrysh, V.I.; Nitsenko, V.S. National features for alternative motor fuels market. *Int. J. Energy Econ. Policy* **2018**, *2*, 226–249. [CrossRef]
15. Cucchiella, F.; Adamo, I.; Gastaldi, M. Biomethane: A renewable resource as vehicle fuel. *Resources* **2017**, *6*, 58. [CrossRef]
16. Armeanu, D.S.; Vintila, G.; Gherghina, S.C. Does renewable energy drive sustainable economic growth? Multivariate panel data evidence for EU-28 Countries. *Energies* **2017**, *10*, 381. [CrossRef]

17. Moldan, B.; Janouskova, S.; Hak, T. How to understand and measure environmental sustainability: Indicators and targets. *Ecol. Indic.* **2012**, *17*, 4–13. [CrossRef]
18. Chang, D.; Chen, S.; Hsu, C.; Hu, A.H.; Tzeng, G. Evaluation framework for alternative fuel vehicles: Sustainable development perspective. *Sustainability* **2015**, *7*, 11570–11594. [CrossRef]
19. Soltani-Sobh, A.; Heaslip, K.; Bosworth, R.C.; Barnes, R. Compressed Natural Gas Vehicles: Financially Viable Option? *Transp. Res. Rec.* **2016**, *2572*, 28–36. [CrossRef]
20. Heaslip, K.; Bosworth, R.; Barnes, R.; Sobh, A.S.; Thomas, M.; Song, Z. *Effects of Natural Gas Vehicles and Fuel Prices on Key Transportation Economic Metrics*; Final Res. Rep.; Washington State Department of Transportation: Olympia, DC, USA, 2014. Available online: <https://www.wsdot.wa.gov/research/reports/fullreports/829.1.pdf> (accessed on 4 September 2018).
21. Pessoa, J.P.; Rezende, L.; Assunção, J. *Flex Cars and Competition in Ethanol and Gasoline Retail Markets*; CEP Discussion Papers dp1251; Centre for Economic Performance: London, UK, 2013; Available online: <http://www.economia.puc-rio.br/lrezende/FlexCars.pdf> (accessed on 5 September 2018).
22. Pouliot, S. Arbitrage between ethanol and gasoline: Evidence from motor fuel consumption in Brazil. In Proceedings of the Economics Present., Post. and Proc. AAEA&CAES Ann. Meeting, Washington, DC, USA, 4–6 August 2013; Available online: https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1007&context=econ_las_conf (accessed on 10 August 2019).
23. Buczaj, M.; Sumorek, A. Analysis of the market of LPG as an alternative vehicle fuel in Poland in 2005–2016. *ECONTECHMOD Int. Q. J.* **2017**, *6*, 47–54.
24. Setiyo, M.; Soeparman, S.; Hamidi, N.; Wahyudi, S. Techno-economic analysis of liquid petroleum gas fueled vehicles as public transportation in Indonesia. *Int. J. Energy Econ. Policy* **2016**, *6*, 495–500.
25. Hao, H.; Liu, Z.; Zhao, F.; Li, W. Natural gas as vehicle fuel in China: A review. *Renew. Sustain. Energy Rev.* **2016**, *62*, 521–533. [CrossRef]
26. Ding, L.; Wu, J. Innovation ecosystem of CNG vehicles: A case study of its cultivation and characteristics in Sichuan, China. *Sustainability* **2018**, *10*, 39. [CrossRef]
27. Salvo, A.; Huse, C. Is arbitrage tying the price of ethanol to that of gasoline? Evidence from the uptake of flexible-fuel technology. *Energy J.* **2011**, *32*, 119–148. [CrossRef]
28. Montasser, G.E.; Gupta, R.; Martins, A.L.; Wanke, P. Are there multiple bubbles in the ethanol–gasoline priceratio of Brazil? *Renew. Sustain. Energy Rev.* **2015**, *52*, 19–23. [CrossRef]
29. Bentivoglio, D.; Finco, A.; Bacchi, M.R.P. Interdependencies between biofuel, fuel and food prices: The case of the Brazilian ethanol market. *Energies* **2016**, *9*, 464. [CrossRef]
30. Laurini, M.P. The spatio-temporal dynamics of ethanol/gasoline price ratio in Brazil. *Renew. Sustain. Energy Rev.* **2017**, *70*, 1–12. [CrossRef]
31. Wik, C.; Niemi, S. Low emission engine technologies for future tier 3 legislations-options and case studies. *J. Shipp. Trade* **2016**, *1*, 3. [CrossRef]
32. Tareen, I.Y.; Wetzstein, M.E.; Duffield, J.A. Biodiesel as a substitute for petroleum diesel in a stochastic environment. *J. Agric. Appl. Econ.* **2000**, *32*, 373–381. [CrossRef]
33. Dincer, I.; Zamfirescu, C. Fossil fuels and alternative fuels. In *Advanced Power Generation Systems*; Elsevier: Amsterdam, The Netherlands, 2014; pp. 95–141. [CrossRef]
34. Annual Energy Outlook. With Projections to 2035. U.S. Energy Information Administration, U.S. Department of Energy. Available online: <https://www.eia.gov/outlooks/aeo/pdf/0383.pdf> (accessed on 7 August 2019).
35. Zorpas, A.A.; Pociovalisteanu, D.M.; Georgiadou, L.; Voukkali, I. Environmental and technical evaluation of the use of alternative fuels through multi-criteria analysis model. *Prog. Ind. Ecol. Int. J.* **2016**, *10*, 3–15. [CrossRef]
36. Havrysh, V.; Nitsenko, V. Current state of world alternative fuels market. *Actual Probl. Econ.* **2016**, *7*, 41–52.
37. Aatola, H.; Larmi, M.; Sarjoavaara, T.; Mikkonen, S. Hydrotreated vegetable oil (HVO) as a renewable diesel fuel: Trade-off between NO_x, particulate emission, and fuel consumption of a heavy duty engine. *SAE Int. J. Engines* **2008**, *1*, 1251–1262. [CrossRef]
38. Liu, Z.; Kendall, K.; Yan, X. China Progress on Renewable Energy Vehicles: Fuel Cells, Hydrogen and Battery Hybrid Vehicles. *Energies* **2019**, *12*, 54. [CrossRef]
39. Leiby, P.; Rubin, J. Effectiveness and efficiency of policies to promote alternative fuel vehicles. *Transp. Res. Rec.* **2001**, *1750*, 84–91. [CrossRef]

40. Kalinichenko, A.; Havrysh, V. Environmentally friendly fuel usage: Economic margin of feasibility. *Ecol. Chem. Eng. S* **2019**, *26*, 241–254. [CrossRef]
41. Kalinichenko, A.; Havrysh, V.; Hruban, V. Heat recovery systems for agricultural vehicles: Utilization ways and their efficiency. *Agriculture* **2018**, *8*, 199. [CrossRef]
42. Kalinichenko, A.; Havrysh, V.; Perebyynis, V. Sensitivity analysis in investment project of biogas plant. *Appl. Ecol. Environ. Res.* **2017**, *15*, 969–985. [CrossRef]
43. Gazzarin, C. Maschinenkosten Agroscope Transfer 142. 2016. Available online: https://www.agroscope.admin.ch/agroscope/de/home/themen/wirtschaft-technik/betriebswirtschaft/maschinenkosten/_jcr_content/par/columncontrols/items/1/column/externalcontent_1062703409.external.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BILmNoL2RILUNIL0VpbnplbH/B1Ymxpa2F0aW9uL0Rvd25sb2FkP2VpbnplbHB1Ymxpa2F0aW9u/SWQ9MzY3OTI=.pdf (accessed on 4 September 2018).
44. Lubbe, P.A.; Archer, C.G. Guide to Machinery Costs Department of Agriculture, Forestry and Fisheries, Pretoria. 2014/2015. Available online: <http://www.daff.gov.za/Daffweb3/Portals/0/Statistics%20and%20Economic%20Analysis/Economic%20Analysis/Guide%20to%20machinery%20costs%202014-15.pdf> (accessed on 1 September 2018).
45. Lips, M. Length of Operational Life and Its Impact on Life-Cycle Costs of a Tractor in Switzerland. *Agriculture* **2017**, *7*, 68. [CrossRef]
46. Edwards, W. Machinery Management. Estimating Farm Machinery Costs. Iowa State University, University Extension. 2015. Available online: <https://www.extension.iastate.edu/AGDm/crops/html/a3-29.html> (accessed on 4 September 2018).
47. Davis, S.C.; Diegel, S.W.; Boundy, R.G. Transportation Energy Data Book: Edition 31, Center for Transportation Analysis. Energy and Transportation Science Division, 2012. Available online: https://tedb.ornl.gov/wp-content/uploads/2019/03/Edition31_Full_Doc.pdf (accessed on 10 August 2019).
48. Davis, S.C.; Williams, S.E.; Boundy, R.G. Transportation Energy Data Book: Edition 36, Center for Transportation Analysis. Energy and Transportation Science Division, 2017. Available online: https://tedb.ornl.gov/wp-content/uploads/2019/03/Edition31_Full_Doc.pdf (accessed on 10 August 2019).
49. E85Prices. 4430 Stations Selling E85 across 2462 Cities in USA. 2018. Available online: <https://e85prices.com/> (accessed on 7 August 2019).
50. MyLPG.UA. Chart of Fuel Prices in Germany. Available online: <https://www.mylpg.eu/stations/germany/prices> (accessed on 4 September 2018).
51. FUELO, CNG. 2018. Available online: <https://de.fuelo.net/fuel/type/methane/year?lang=en> (accessed on 4 September 2018).
52. Sweden Tips. Travel Guide and Booking Portal. Fuel Prices in Sweden: Petrol/Gasoline and Diesel. Available online: <http://www.swedentips.se/fuel-prices/> (accessed on 5 September 2018).
53. Atamanyuk, I.P. Polynomial algorithm of optimal extrapolation of stochastic system parameters. *J. Upravlyayushchie Sistemy i Mashiny* **2002**, *1*, 16–19. [CrossRef]
54. Atamanyuk, I.P. Algorithm of extrapolation of a nonlinear random process on the basis of its canonical decomposition. *J. Kibernetika i Sistemnyj Analiz* **2005**, *2*, 131–138. [CrossRef]
55. DAIZEN. Wheeled CNG-Powered Tractor MTZ-1221.2 Belarus. 2018. Available online: http://www.xn--80ahehj0a.xn--p1ai/goods/61479722-kolesny_traktor_mtz_1221_2_belarus_s_gazobalonnym_oborudovaniyem (accessed on 7 August 2019).
56. Omnitek Develops Diesel-to-Natural Gas Engine Conversion Kits for Mercedes OM904/OM906. Green Car Congress, 2012. Available online: <https://www.greencarcongress.com/2012/04/omnitek-20120419.html> (accessed on 27 January 2019).
57. Smith, M.; Gonzales, J. Costs Associated with Compressed Natural Gas Vehicle Fueling Infrastructure. September US Department of Energy, 2014. Available online: https://www.afdc.energy.gov/uploads/publication/cng_infrastructure_costs.pdf (accessed on 10 August 2019).
58. Jung, H.; Leone, T.; Shelby, M.; Anderson, J.; Collings, T. Fuel Economy and CO₂ Emissions of Ethanol-Gasoline Blends in a Turbocharged DI Engine. *SAE Int. J. Engines* **2013**, *6*, 422–434. [CrossRef]
59. Leone, T.; Olin, E.; Anderson, J.; Jung, H.; Shelby, M.; Stein, R. Effects of Fuel Octane Rating and Ethanol Content on Knock, Fuel Economy, and CO₂ for a Turbocharged DI Engine. *SAE Int. J. Fuels Lubr.* **2014**, *7*, 9–28. [CrossRef]

60. US Department of Energy, New Flex-Fuel Vehicles. Available online: <https://www.fueleconomy.gov/feg/PowerSearch.do?action=alts&path=3&year1=2017&year2=2018&vtype=E85&srctype=newAfv> (accessed on 5 September 2018).
61. Jadhav, A.; Hulwan, D.B. Experimentation & Simulation of Dual Fuel (Diesel-CNG) Engine of Off Road Vehicle. *Eur. J. Adv. Eng. Tech.* **2017**, *4*, 629–636.
62. Mirica, I.; Pana, C.; Negurescu, N.; Cernat, A.; Nutu, N.C. Dual fuel diesel engine operation using LPG. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2016; Volume 147, p. 12122. [[CrossRef](#)]
63. Valtra Dual Fuel Tractors—The Natural Choice. Available online: <http://www.valtra.com.au/dual-fuel.aspx> (accessed on 5 September 2018).



© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).