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CURRENT STATE OF WORLD ALTERNATIVE MOTOR FUELS MARKET

The relationship between social formations and energy resources consumption, key world trend of the motor fuels market have been explored. Economic factors that affect production and use of alternative motor fuels are studied. National features of the alternative fuels market are outlined.

Keywords: *biofuel; alternative motor fuels; biodiesel; bioethanol.*

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СУЧАСНИЙ СТАН СВІТОВОГО РИНКУ АЛЬТЕРНАТИВНИХ МОТОРНИХ ПАЛИВ

У статті досліджено зв'язок між соціальними формаціями і споживанням енергетичних ресурсів, а також основні тенденції ринку моторних палив. Проаналізовано економічні фактори, що впливають на виробництво і застосування альтернативних моторних палив. Виявлено основні національні особливості ринку альтернативних палив.

Ключові слова: *біопаливо; альтернативні моторні палива; біодізель; біоетанол.*
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СОВРЕМЕННОЕ СОСТОЯНИЕ МИРОВОГО РЫНКА АЛЬТЕРНАТИВНЫХ МОТОРНЫХ ТОПЛИВ

В статье исследована связь между социальными формациями и потреблением энергетических ресурсов, а также основные тенденции рынка моторных топлив. Проанализированы экономические факторы, влияющие на производство и применение альтернативных моторных топлив. Выявлены основные национальные особенности рынка альтернативных топлив.

Ключевые слова: *биотопливо; альтернативные моторные топлива; биодизель; биоэтанол.*

Problem statement. There are two most serious global problems nowadays – energy security and ecology. Their actuality is conditioned by the growing role of the environment on efficient functioning of national economies under tightening competition at the markets of resources and products.

Ecological problems caused by fossil fuels use are intensifying day by day. Therefore, application of alternative motor fuels, including renewable ones, strengthens energy security of all states, promotes national competitiveness and improves overall ecological situation.

Countries of the world have different reserves of fossil resources, climatic conditions, legislation, level of economy and science development. These factors impact the alternative motor fuels application, their types and scope of use.

It is important to study the prospective ways of alternative motor fuels use, reveal the general patterns at this market and consider the world best practices for Ukraine.

Recent research and publication analysis. Theoretical and practical aspects of alternative motor fuels market are explored in the works of foreign and domestic authors. J. Bell (1999) and E. Toffler (1999) studied general tendency of society development in its relation to energy resources use, including renewable ones. The impact

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of biodiesel on the market situation was studied by M. Kobets (2007); the influence of biofuels on the planet's finite supply of fossil fuels and sustainable future were studied by L.P. Koh and J. Ghazoul (2008); the criteria for comparing the efficiency of energy resources and technologies were studied by C.A.S. Hall and C.J. Clevelend (2005), R. Heinberg (2009), A.N. Goloskokov (2011) and many others.

However, this issue is still insufficiently studied and requires further scientific research.

The research objectives are to identify specific national aspects of alternative motor fuels market; to develop scientific and practical recommendations for its development in Ukraine.

Methodology. Methodological bases for this study are the research developments of domestic and foreign scientists, legal acts, and statistical data. For the study of the effectiveness of different types of fuels economic mathematical modelling is applied.

To make a decision on the use of fuel it is necessary to have information not only on their physical and chemical properties, but also their economic characteristics. One of them is the cost of fuel energy. Estimation of the effectiveness of different kinds of fuels depends on the values determined as follows:

$$CE = \frac{Fpr}{Q \times \rho}, \text{USD/GJ}, \tag{1}$$

where Fpr – the price of fuel, USD/m^3; Q – lower heating value of fuel, MJ/kg; ρ – fuel density, t/m^3.

In the case of mixed fuel the cost of energy is determined as follows:

$$CE = \frac{\sum_{i=1}^{n}(Fpr_i \times g_i)}{\sum_{i=1}^{n}(Q_i \times \rho_i \times g_i)}, \text{USD/GJ}, \tag{2}$$

where Fpr_i – the price of the i-th component of the fuel, USD/m^3; Q_i – lower heating value of the i-th component of the fuel, MJ/kg; ρ_i – the density of the i-th component of the fuel, t/m^3; n – the number of components; g_i – part of the i-th component of the fuel.

Efficiency of internal combustion engine depends on a number of factors, including the type of a fuel used. Thus, efficiency of diesel engine D-245.12S at maximum torque when running on diesel fuel is 37.5%, and under the mixture consisting of 40% rapeseed oil and 60% diesel fuel – 37.2%.

Studies for spark-ignition brand ZMZ 405.2 have shown the following. The highest efficiency is observed when an engine operates on gasoline and propane – 33.7%. When an engine is running on methane the efficiency drops to 31%. The maximum efficiency for biogas does not exceed 29%.

Therefore, it is advisable to determine the cost of energy that will be used for useful work

$$CEE = \frac{CE}{\eta} = \frac{\sum_{i=1}^{n}(Fpr_i \times g_i)}{\eta \times \sum_{i=1}^{n}(Q_i \times \rho_i \times g_i)}, \text{USD/GJ}, \tag{3}$$

where η – the efficiency of the engine.

This formula can be used to compare different fuels.

Production of biofuels will be economically feasible if their energy cost is less than the similar indicator for petroleum fuel, the cost of which is equal to the cost of bioharvest used. A mathematical expression of the above conditions is as follows (Havrysh, 2007):

$$K = \frac{V_b}{V_o} \times \frac{Q_b}{Q_o} \times \frac{\rho_b}{\rho_o}, \quad (4)$$

where Q_b, Q_o – lower heat value of biofuels and petroleum fuel accordingly, MJ/kg; ρ_b, ρ_o – density, respectively, of biofuels and petroleum, t/m^3; V_b – volume of biofuel, m^3; V_o – volume of petroleum fuel, m^3.

It is necessary to take into account the selling of by-products. For biodiesel these are cake and glycerin, for ethanol – carbon dioxide and dry fodder. The sale of these products allows getting additional funding for the purchase of petroleum fuel. This can improve the value of biofuels production expediency.

In this case the equivalent volume of biofuels will be determined as follows

$$V_b = \varphi \times U + U \times \frac{\sum_{i=1}^{n}(m_i \times Cpr_i)}{Fpr} \times \frac{Q_o \times \rho_o}{Q_b \times \rho_b}, \quad (5)$$

where n – the number by co-products; m_i – dimensionless output of the i-th by-product; Cpr_i –market price of the i-th co-product, USD/t; U – the yield of energy crop, t/ha; φ – the output of biofuel from a crop, m$^3 \cdot$ t^{-1}.

Then the expression for the criterion would be:

$$K = \varphi \times \frac{Fpr \times Q_b \times \rho_b}{Cpr \times Q_o \times \rho_o} + \frac{\sum_{i=1}^{n}(m_i \times Cpr_i)}{Cpr}. \quad (6)$$

Thus, economic feasibility of biofuels production mainly depends on the ratio of petroleum fuel and energy crop prices. Therefore, the price of energy plants (taking into account the by-products) must not exceed (Havrysh, 2007)

$$Cpr < \varphi \times \frac{Fpr \times Q_b \times \rho_b}{Q_o \times \rho_o} + \sum_{i=1}^{n}(m_i \times Cpr_i). \quad (7)$$

Alternative motor fuels. Conventional those are fuels derived from petroleum. Alternative fuels are non-petroleum fuels. Which use can improve both environmental and economic indicators of the related activities.

The first group includes petroleum products such as gasoline and diesel fuel (Figure 1).

Alternative energy sources are divided into renewable and non-renewable.

As a renewable resource for motor fuels production can be used fats, biomass, agricultural, industrial and household wastes etc. Non-renewable fuels include natural gas, liquefied petroleum gas (LPG), gas condensate, synthetic fuels derived from coal and oil shale, dimethyl ether manufactured from natural gas etc.

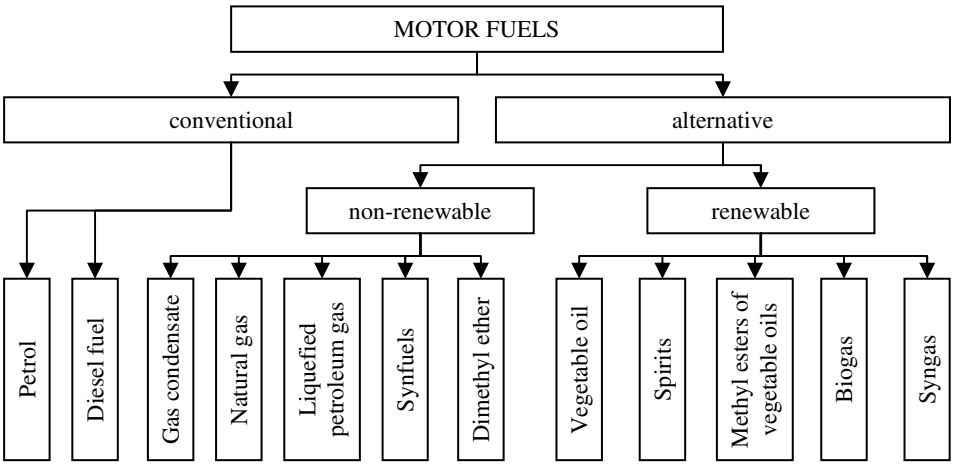

Figure 1. **Classification of motor fuels,** *compiled by the authors using* (Markov et al., 2014)

Renewable fuels are made of raw materials of organic origin. They include vegetable oils, methyl esters of vegetable oils, alcohol fuels (bioethanol, methanol, buthanol, oxygen-containing additives), biogas, syngas.

It should be noted that most of physics and chemical properties of biofuels differ from conventional petroleum properties. And this complicates their use. Therefore, internal combustion engines can use mixed fuels containing both petroleum and non-petroleum components. Their properties are similar to conventional fuels. The following combinations are used most widely: diesel fuel and vegetable oils; diesel fuel and vegetable oil methyl esters; gasoline and bioethanol.

Alternative motor fuels by groups can be classified as follows: synthetic fuels; fuel oil with additives alcohols or ethers; non-oil fuels (LPG and compressed natural gas, liquefied propane, butane, dimethyl ether, hydrogen). For the use of alternative motor fuels of the first group does not require any engine modification, including fuel system or infrastructure changes. Alternative motor fuels of the second group require certain fuel system and infrastructure change. Alternative motor fuels of the third group require modification of the engine, the fuel system, and fuel supply infrastructure.

Feasibility of growing energy raw materials. Let us consider the expediency of crops cultivation for biofuel production. The calculations results for biodiesel production in Ukraine are shown in Figure 2. As can be seen, the production of this kind of fuel without economic incentives is inappropriate. There are only few cases when biodiesel production is economically justified. As it was observed in the second half of 2014.

As to bioethanol production, the situation is somewhat different. The efficiency depends on raw materials and petrol that is replaced. The value of the efficiency criterion for bioethanol production from sugar beet, wheat and corn to replace gasoline A-95 are given in Table 1. The results have been obtained using formula (6) and market prices (as of November 2015).

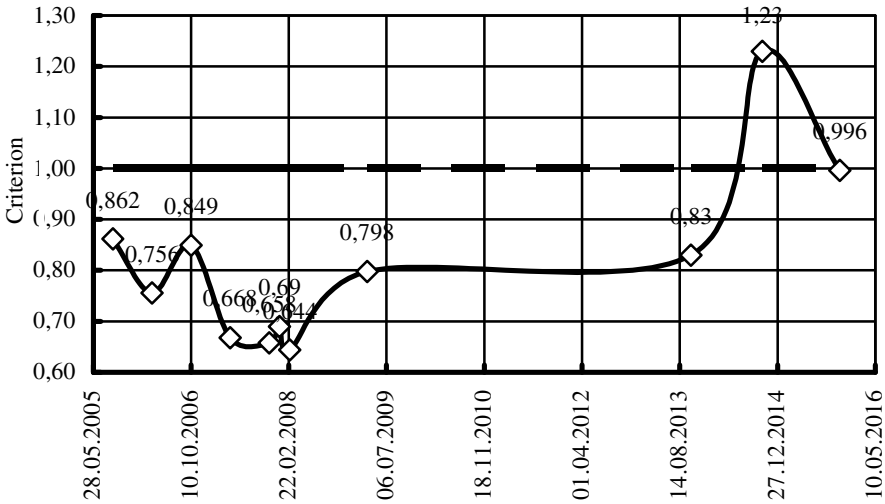

Figure 2. **History of the criterion K for biodiesel in Ukraine,** *developed by the authors using* (Dubrovin et al., 2004 and market prices)

Table 1. **Criterion for bioethanol production in Ukraine,** *developed by the authors using* (Dubrovin et al., 2004 and market prices)

Raw material	Output of ethanol from crop, $m^3 \cdot t^{-1}$	Mark of petrol A-95
Corn	0.38	1.37
Sugar beet	0.085	1.25
Wheat	0.35	1.14

With regard to the EU countries, at the present level of motor fuel prices, biodiesel production can be economically feasible if the rapeseed price is no more than 480 EUR/t. The calculations were made by using formula (7). In some countries affected by high prices for conventional fuel biofuel production is impossible due to climatic conditions.

Biofuels production. Biofuels production is mostly developed in the countries with favorable climatic conditions, agricultural efficiency and appropriate government support. Thus, the average yield of bioenergy raw materials for bioethanol production is, t/ha: sugar cane (Brazil) – 77; corn (US) – 10.8; maize (EU) – 6.94; Sugar beet – 67.85 (Crop Monitoring in Europe, 2012; Perspectivy..., 2012). This allows producing the following volumes of bioethanol from l/ha: Brazil – 5621; USA – 4320; EU (corn) – 2776; EU (sugar beet) – 7463. Due to low production cost of sugarcane bioethanol production is more economically attractive in Brazil. In the EU countries, despite high bioethanol yield per unit area, due to relatively high production cost of bioenergy raw materials, bioethanol production is less competitive in comparison with Brazil.

The situation in biodiesel production is somewhat different. The average yield of rapeseed in the EU is 3.0 t/ha. High rates have the following countries, t/ha: Belgium – 4.11; Germany – 3.66; United Kingdom – 3.49; Denmark – 3.54 (Crop Monitoring in Europe, 2012). This creates the conditions for effective production of

biodiesel. That is why the EU is the world leader in production and use of biodiesel. Significant volumes of raw materials and readymade biodiesel are also imported, however.

Economic encouragement. The world practice shows that using alternative fuels is attractive either because of lower cost, or because of economic incentives. Examples of the first direction are compressed natural gas (CNG) or bioethanol in Brazil.

Energy density of ethanol is approximately 30% less than that of petrol. Therefore, to ensure the economic attractiveness the price of biofuel should also be at least 30% less than petrol price. Today, this condition is fully satisfied only in Brazil due to favorable climatic conditions for sugar cane. Cheap raw materials allow producing bioethanol with low production costs – 0.25 USD/l (Fay, 2013).

However, in most cases, the production cost of biofuels and synthetic fuels are higher than that of conventional fuels. That is why the following economic incentives are important:

- reduction of the excise tax;
- tax credit;
- compensation of investment costs at alternative fuel plants;
- quotas for biofuels consumption;
- environmental payments;
- subsidies to producers of bioenergy raw materials.

Their use helps increase biofuels consumption. For example, in Germany, biodiesel consumption reached the record levels (Figure 3). First of all, to bring biofuels to the market it is necessary to apply a reduced excise tax, and further they use quotas and support for producers of bioenergy raw materials (EBB, 2014; Federal, 2003, 2005, 2011; VDB, 2011). As can be seen in Figure 3, the reduction of financial support has resulted in a decline in biodiesel production.

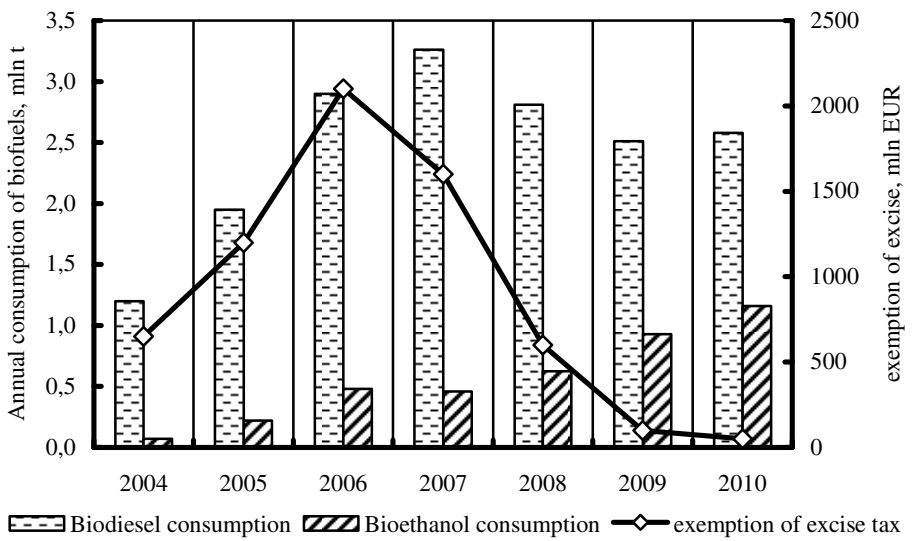

Figure 3. **Dynamics of biofuels consumption in Germany,** *compiled by the authors on the basis of* (EBB, 2014; Federal, 2003, 2005, 2011; VDB, 2011)

Production and use of alternative fuels, including biofuels, should be economically feasible. As a rule, in the EU production costs of biofuels are higher than petroleum fuels. For example, in 2010, production costs in Germany were equal to, EUR/liter: diesel fuel – 0.45; gasoline – 0.42; biodiesel – 0.84; bioethanol – 0.58. Today, tax exemptions for biofuels are not provided. Exceptions go for biofuels of second generation (cellulosic ethanol), biogas and bioethanol E85, which are exempt from excise tax. Pure biodiesel (B100) and vegetable oils as fuel to 2012 were subject to preferential taxation. The use of expensive biofuels is stimulated by a quota system (Rauch, 2012).

Introduction of alternative fuel motor in agricultural production may be constrained by the available programs to support producers. For example, in the EU preferential prices for diesel fuel limit the spread of ecologically safer fuels.

There are countries with low and high value of excises. For example, the first group includes the United States. In this country at the beginning of 2015 excise taxes on motor fuels were equal to, USD/gallon (EUR/1000 liters): gasoline – 0.2412 (59.29); diesel fuel – 0.249 (61.21); gasohol – 0.2408 (59.19) (State Motor Fuel Tax Rates, 2015). Low taxes reduce the range of pricing. As a result compressed natural gas is the most economically attractive motor fuel (Figure 4) (Clean Cities Alternative Fuel Price Report, 2015). Moreover, CNG is economically attractive, even with a sharp drop in crude oil price (Figure 5).

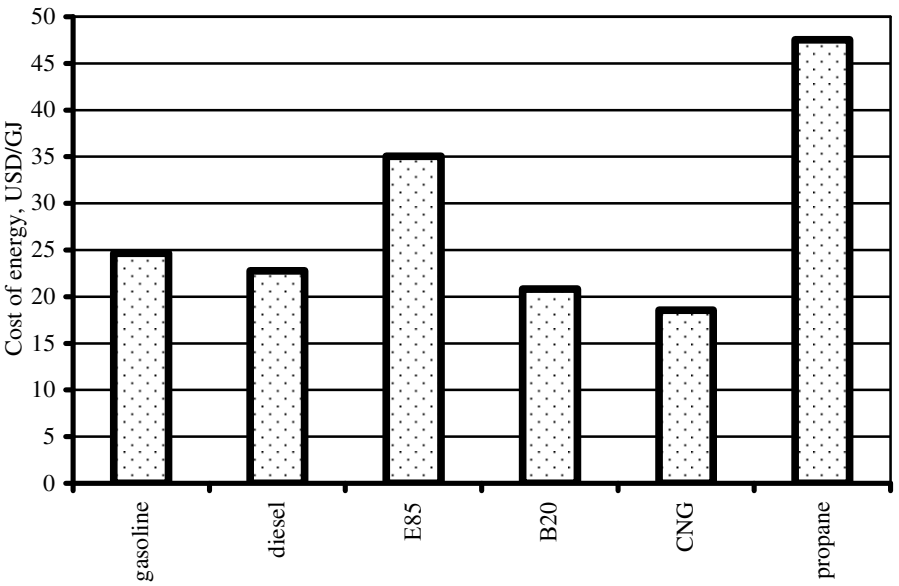

Figure 4. **The cost of fuel's energy in the USA**
(Clean Cities Alternative Fuel Price Report, 2015)

Even though biofuels are more expensive than conventional fuels, their consumption in the USA has been increasing recently. The USA is the biggest producer and consumer of bioethanol (the annual production – 18.8 mln tons of oil equivalent) and biodiesel (the annual production – 4.8 mln m^3 or 4.0 mln tons of oil equivalent) (The Statistics Portal, 2014). It becomes possible due to strict state legislation.

In accordance to "Energy Independence and Security Act of 2007" there are the following main targets (Energy Independence and ..., 2007):

• by 2022, the annual use of 105 mln tons of renewable fuel, which amount to 20% of the current consumption motor fuels in the United States. Of these, 60% (64 mln tons) is supposed to be the second generation biofuels;

• increase fuel filling stations E85 by 5% each year to the point when 50% of all gas stations can sell fuel E85;

• Automakers are required to increase the production of flexible fuel vehicles (FFV) 10% per year to achieve 100% release of these machines.

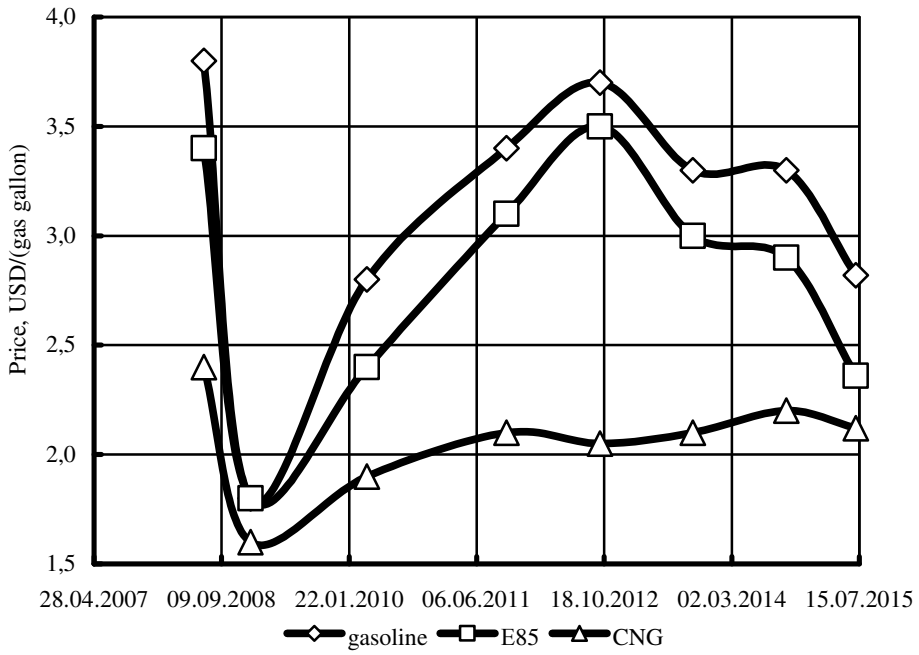

Figure 5. **History of motor fuels prices in the United States,** *compiled by the authors on the basis of* (Clean Cities Alternative Fuel Price Report, 2015)

In some countries in the EU, high excise taxes on motor fuels are applied. They reach on average 466 EUR/t for gasoline and 375 EUR/t for diesel. This allows forming an economically attractive price for alternative fuels by regulating the rates of excise taxes.

A number of countries have large reserves of crude oil and pursue the policy of low prices for motor fuels inside the country (Figure 6) (The Statistics Portal, 2014). Naturally, this does not stimulate the development of alternative energy sector.

On the contrary, a country where fossil energy resources are scarce, but there is a clear energy strategy, production of alternative fuels is developing rapidly.

As for Ukraine, since 2015 the alternative fuel 95 eco+ is being sold. It contains ethanol, and its price is 18.99 UAH/l (as of October 2015). Noteworthy comparison, the a price for A-95 is 20.99 UAH/l.

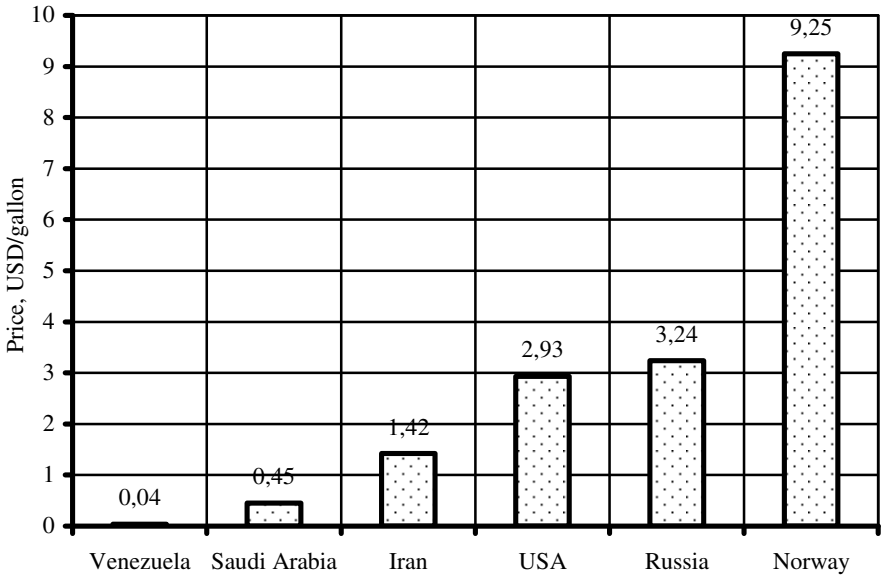

Figure 6. **Gasoline price in some countries (October 2014)**
(The Statistics Portal, 2014)

Encouraging the use of gaseous motor fuels. To encourage the use of gaseous fuels such as natural gas and especially biomethane the reduced tax rates are applied. For example, in the Baltic States biomethane is taxed at zero rate, and natural gas is taxed significantly lower than fossil fuels (Figure 7) (Benjaminsson, 2013).

There is an interesting experience in Sweden concerning the encouragement use to alternative fuels. It covers all areas – from investment in fuels to environmental charges (Benjaminsson, 2013):

- investments in production of biofuels;
- reducing income taxes;
- lack of parking fees;
- government awards for eco-friendly cars;
- reducing taxes on gas-cylinder cars.

For example, new environmentally friendly cars are exempt from taxes for 5 years. For comparison, annual environmental payments for diesel cars are 460 EUR, and for gasoline cars – 230 EUR.

Construction of new biogas and biomethane plants gets investment grants ranging from 20 to 30% of the total costs (Benjaminsson, 2013).

Today China People Republic ranks #1 in the world by biogas production (15 bln m^3 per year) (Li, 2014).

Ukraine also has some experience in biogas production. But in Ukraine renewable gaseous fuel is usually used for co-generation. For example, JSC "Danosha" produces 13,000 m^3 of such fuel per day. It can be used as a motor fuel.

Natural gas is a widespread motor fuel. In the world there are more than 22 mln natural gas vehicles. They consume more than 2 bln m^3 of gas monthly. There are some factors influencing its use in different countries:

- reserves on gasfields;
- prices;
- availability of gaseous fuels;
- infrastructure around refueling stations.

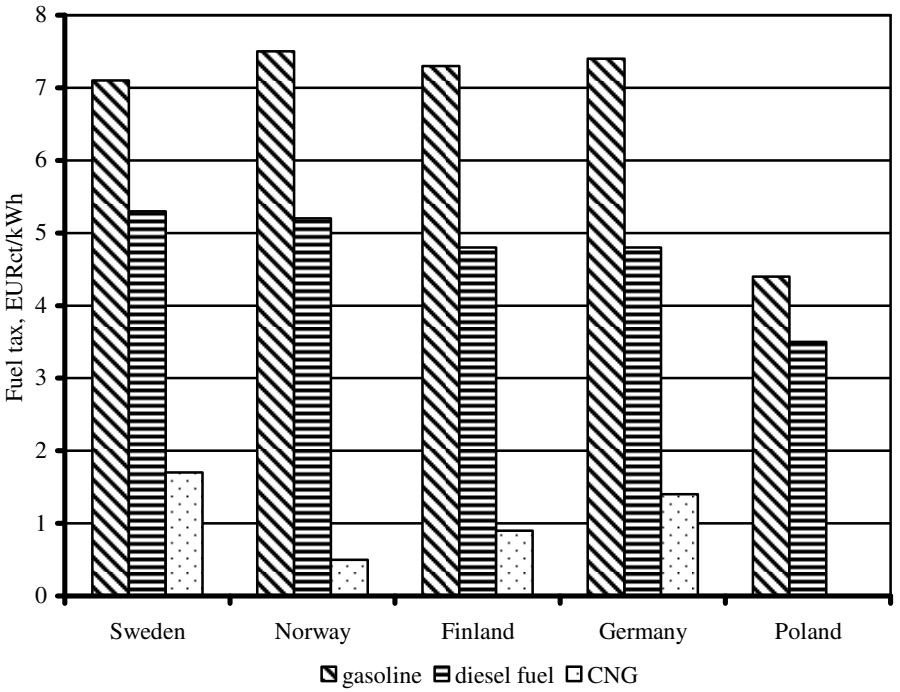

Figure 7. **Tax rates on fuels in the selected Baltic States** (Benjaminsson, 2012)

Russia has the biggest in the world reserves of natural gas. However, there are only 90,000 natural gas vehicles in the country. The main reasons for this are large areas of the country as such (and therefore, often long distance between destination points) and cheap petroleum. This makes it difficult to develop necessary infrastructure. The same situation is observed in the USA.

Conclusions. Development of the biofuels market in the world is dictated by the reduction in conventional petroleum energy resources, and drastic environmental degradation. These reasons led to stable growth in production of alternative fuels including biofuels.

Provision of energy resources in any state can be carried out in two directions.

First, economically developed countries (with relatively low self-sufficiency in primary energy resources) cover their deficit by means of imports. Sufficient financial resources allow stimulating the use of all kinds of alternative motor fuels.

Second, countries with underdeveloped economy, due to lack of funds, use the strategy of self-limitation of energy consumption and alternative energy self-sufficiency. They are developing alternative fuels, which are cheaper than conventional ones. This way is very much preferable for Ukraine.

Currently, the most widespread alternative motor fuel is compressed natural gas as it is the cheapest fuel.

To intensify biofuels use in Ukraine it is necessary to concentrate on the actions which do not require budget financing:

- to stimulate the use of flexible fuel vehicles;
- to apply effective excise tax exemption for biofuels;
- state regulation must realistically consider the applicable volume of renewable fuels.

Taking into account that Ukraine is striving for the EU, the legislative basis for alternative fuels use has to be harmonized with the EU legislation. This implies Ukraine should initiate the second generation of biofuels production.

Since Ukraine already has experience of biogas production it is expedient to stimulate the use of biogas (biomethane) as a motor fuel.

Prospects for further research is to investigate the synergy effect from reducing impact of excise duty on biofuels, which concerns import substitution, strengthening energy independence of the state, improving trade balance etc.

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