Alternative Vehicle Fuel Management: Impact on Energy Security Indicators

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Abstract. Land transport consumes primarily oil products. Their use effects on climate change. A tendency of crude oil price increasing, uneven allocation, and exhaustibility forces to look for alternatives. Alternative vehicle fuel can to reduce energy dependence and meet ecological requirement. The aim of the study was to reveal the basic principles of the alternative vehicle fuel management and its influence on energy security indicators. The fundamental objectives and principles of alternative fuel management were reviewed. The energy security indicators which are affected by the use of alternative fuels were considered. The primary goal of the alternative vehicle fuel management is profit optimization and strengthens the energy security indicators. The energy security indicators can be improved by the use of indigenous fuels (both renewable and non-renewable) and by increasing the diversification of energy resource supplies.

Keywords: Alternative fuel management · Energy security · Indicator · Energy market · Environment

1 Introduction

Scientific and technical progress in the developed countries has been accompanied by acceleration in the growth rate of energy consumption. In 2016, primary world energy consumption exceeds 13 276 billion tons of oil equivalent. Most of it is crude oil (up to 4418 billion tons or 33.28%) [4]. Transport mainly uses petroleum fuels. Therefore the overall trends in the oil market should be considered.

At the moment the total estimated reserves of hydrocarbon fuels of the planet exceed 12,5 trillion tons, most of which is coal. Crude oil accounts for about 21% [4]. The world energy market is divided unevenly by the production and consumption.

One of the most important tasks is the forecast of extraction of energy resources. The first man who started researching the problem of energy resources scientifically was King Hubbert. He formulated the basic principle of peak theory. It describes depletion of fossil resources [34]:

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– production starts from zero;
– production increases to its maximum level (which is called a peak), which can never be bridged;
– after passing the peak, there comes the fall of production until the resource is exhausted.

Standard Hubbert curve has the form of a bell. For example, in Ukraine a crude oil production curve complies with the Hubbert peak theory (Fig. 1) [24, 28]. The modern tendency can be described as follows. Crude oil holds a dominant position despite there was a decrease in its share. There has been an increase in natural gas' market share. Renewable energy utilization' share has increased [4].

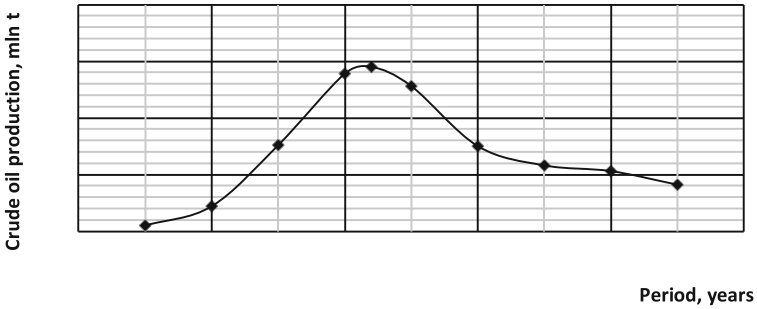

Fig. 1. Crude oil production history in Ukraine (adapted from [19])

Today the dominant global trend is the growth of the cost of fossil energy resources. Therefore, the mid 1990s renewable energy resources in general and biofuels in particular were started to develop. It is caused by two main reasons. The first reason is the environmental protection and reduced greenhouse gas emissions. The second one is to ensure energy independence of energy-importing countries [18].

As a result of the world crude oil reserve reduction, there is a tendency of the crude oil price increase. This makes transport, and hence the economy of each country, dependent on the availability of crude oil. Therefore, energy security for the transport sector is often equated with crude oil security and totally national energy security.

That is why the most important problem for the transport sector is the replacement of petroleum fuels by non-petroleum ones, i.e. alternative fuels. By 2020 the European Union is going to transform about a quarter of the entire European vehicle fleet to alternative fuels: compressed natural gas (CNG), biogas, hydrogen (fuel cells), liquefied petroleum gas (LPG), and biofuels. Each country has its own national features [11].

To produce and utilise alternative vehicle fuels, alternative vehicle fuel management should be applied. The aim of the paper was to reveal the basic principles of the alternative vehicle fuel management and impact of its application on energy security indicators.

2 Materials and Methods

Although the energy security concept is old, its indicators and definition have been studying last decades [1, 20]. The energy security concept has received great attention and has been the subject of many studies within different fields of science [14, 22, 29]. In the 21st century publications on energy security have emerged as being of great importance [33]. Many reasons for this growing interest are the following: increased energy prices [29], the growing dependence on energy [15, 16], the global energy supply crisis [2], climate issues [3, 19], etc.

The first available record of a definition of energy security was made by Willrich [32]. He defined energy security as: 'Assurance of sufficient energy supplies to permit the national economy to function in a politically acceptable manner.' Afterwards many scientists tried to make own definitions by including a certain parameters in the definition [7, 10, 13]. They offered a number of indicators to measure energy security. In our study we used the most widespread indicators [6, 12].

Total Primary Energy Supply Self Sufficiency ratio (*TPESR*) is an important measurement of the strength in energy security. It indicates of how dependant the country on internal sources is. It is calculated as

$$TPESR = \frac{IP}{TPES} \cdot 100\%$$

where *IP* is the indigenous production; *TPES* is the total primary energy supply.

Usually, the Reserve/production ratio (*RPR*) is used as an indicator to show the remaining amount of fossil energy resources

$$RPR = \frac{PR}{PP} \text{ years},$$

where *PR* is the proven reserves of energy resources; *PP* is the primary energy production.

For biofuels Reserve-to-Production Ratio is equal to infinity.

Energy intensity (*EI*) is an important indicator to compare national economies. It is calculated as

$$EI = \frac{TPES}{GDP} \text{ toe/mln EUR},$$

where *TPES* is the total primary energy supply, toe; *GDP* is the gross domestic product, mln EUR.

National energy dependency for different energy sources is found as

$$ED = \frac{ERI}{GIE},$$

where *ERI* is the import for different energy resources; *GIE* is the gross inland energy.

Sectoral indicators give information about share of alternative fuels (resources). For example, shares of alternative fuel in transport is equal to

$$SB = \frac{BC}{PDC} \cdot 100\,\%,$$

where BC is the alternative fuels consumption; PDC is the petrol & diesel fuel consumption.

To design optimum diversity strategies, the diversity must to be measured. To reach the above Herfindahl-Hirschman Index (HHI) and Shannon-Wiener Index (SWI) may be used. The SWI and HHI can be calculated as [11, 20, 21, 26]

$$SWI = -\sum_{i=1}^{n} (p_i \cdot \ln p_i),\ HHI = \sum_{i=1}^{n} p_i^2.$$

where p_i is the share of i^{th} alternative energy resource; n is the amount of energy resources.

The optimal value of SWI should exceed 2 [26].

Energy price is a widespread indicator. The price of crude oil has fluctuated but has a gradual rise. It directly affects the formation of vehicle fuel prices and impacts on alternative fuels too [31].

Detailed data collection has been carried out. Literature, statistics and websites were used. The further calculations were made based on information collected.

3 Results

3.1 Alternative Fuel Management: Basic Principles

Both conventional and alternative fuels can be used by transport. Traditional fuels are fuels of oil origin. They include diesel fuel, gasoline, kerosene, etc. Alternative fuels are fuels of non-oil origin. They include biodiesel, bioethanol, biogas, compressed natural gas, liquefied petroleum gas, etc. Their use can improve both environmental and economic indicators of economic activity. Alternative energy sources are divided into non-renewable and renewable ones.

Non-renewable alternative energy sources are natural resources and materials that can be used by humans for energy production. Firstly, they can be classified as fossil fuels and their by-products: coal and brown coal, shale, peat, natural and petroleum gas. They are also wastes of some industries: metallurgy, chemical and thermochemical processing of carbon and hydrocarbons, etc.

Renewable alternative energy sources are the sources of continuously existing or recurrent environmental flows of energy: solar, wind, thermal energy of the Earth, of the seas and oceans, rivers, biomass (plants and animals). To produce renewable fuels, renewable resources (vegetable oil, animal fats, biomass, wood, agricultural and household wastes, etc.) can be used.

To reduce fuel costs and strengthen energy security, the use of non-petroleum fuels are increasing worldwide. Therefore, an effective control system for alternative fuel utilization is needed.

We propose the following definition of alternative vehicle fuel management "Alternative vehicle fuel management is the activity aimed at the effective use of alternative fuels to maximize profits (minimization of costs), improve ecological features, and strengthen the competitive positions and energy security indicators".

The subject of Alternative Vehicle Fuel Management is the patterns and trends of production and use of the alternative fuels, including renewable, the principles of production control as an energy ecology-friendly system in the whole system of social reproduction. Alternative fuel management may be considered as a part of energy management, fleet management, and fuel management.

Fleet management is aimed at the efficiency in fleet operations. Many transport companies rely on fleet managers to maximize profitability, and mitigate risks of their operating activity [30]. Fleet management carries out a range of functions, including fuel management. Fuel management systems are used to maintain, control and monitor fuel consumption and its stock, as a means of business. It is designed to effectively measure and manage the use of fuel within the transportation. Since there are traditional and alternative fuels, it is logical that the alternative fuel management can be an integral part of fuel management and vehicle management in general.

The main goal of energy management is to maximize profits through minimizing manufacturing costs, particularly for energy resources. Meanwhile, both environmental and economic parameters of the production should not be deteriorated. An important role is played by the use of alternative fuels, including renewable energy. On this basis, the main tasks of alternative fuel management can be formulated as follows:

- reducing utilization of traditional fuels;
- development of new types of alternative fuels which have advantages over conventional fuels;
- adaptation of vehicles for the use of alternative fuels;
- development of competitive technologies to produce alternative fuels, including renewable fuels;
- search for new and environmentally friendly ways to increase the return on investments in the alternative fuel producing.

The main results, which are planned to achieve by alternative fuel management, can be divided into four groups: economic, environmental, ensuring the competitiveness and strengthening national energy security.

3.2 Impact on Energy Security Indicators

Imports of crude oil and other fossil hydrocarbon energy resources have a direct impact on energy security and the balance of the national economy. So it should be reduced to minimum acceptable levels to ensure energy, economic and political security. Fuel imports from one source must not exceed 30% of the total energy balance. An important role in this is the use of alternative fuels, including renewable ones.

Alternative fuel utilization has been increasing last decades. The world's energy infrastructure has begun to change towards alternative fuels for the last 20 years. There were companies that are engaged in the of alternative fuel management activity [25].

Biofuels plays an important role. The use of biofuels in the transport across the EU has primarily been driven by concerns around climate change issues. But only indigenous biofuels production can allow countries to improve their energy security by reducing their dependence on imported oil. In the USA the share of non-conventional fuels is 8,1% and biofuels – 5,1%. In the EU market penetration is 5,5% for bioethanol and 7,3% for biodiesel [8]. In Brazil market penetration is higher: 45% for bioethanol and 7,9% for biodiesel [5]. It improves sectoral indicators, national energy dependence and Total Primary Energy Supply Self Sufficiency Ratio.

Because of diversification strategy, in the EU countries the HHI value and the SWI value were improved. According to our calculations (on the basis of [9]), from 2000 to 2015 there has been a rise in SWI from 1,141 to 1,169 and in HHI from 0,369 to 0,387.

The most widespread alternative fuel in the world is compressed natural gas. From 1996 to 2018, the number of natural gas vehicles (NGV) has increased from 850 thousand to 25 million [23]. This is a result of its economical attractiveness. It is important to note that imported gaseous fuels are unlikely to improve the energy security indicators except the diversification one.

Thus in Ukraine in 2017 the share of gaseous fuels was around 31% [27]. But Ukraine imported natural gas and liquefied petroleum gas, so it improves diversification and cost indicators only. Pakistan is short of crude oil reserves too. In 1980s Pakistan launched CNG programs and today its NGV fleet takes 4th position in the world [23]. Currently its CNG industry annually consumes around 3,4 billion natural gas (nearly 8% of national gas production) [4, 17]. The share of compressed natural gas in transport is 23,1%. The utilization of this fuel improves TPESP and national energy dependency. The SWI for the above countries is: Ukraine – 1,06 and Pakistan – 1,01.

Alternative fuel management can make transport systems less vulnerable to fuel supply and fuel costs fluctuation. It encounters many problems (imperfect standards, immature technologies and unnoticed potential benefits). Despite these constraints, alternative fuel management is growing in the world.

The implementation of the alternative fuel management strategy will improve the energy security indicators of any country (Table 1).

Table 1. Impact of alternative fuel management strategy on energy security indicators

Indicator	Positive impact
Total Primary Energy Supply self sufficiency ratio (*TPESR*)	An increase of indigenous fuel production
Reserve/production ratio (*RPR*)	For biofuels Reserve-to-Production Ratio is equal to infinity
Energy intensity	Alternative fuel utilization reduces transportation costs and it results in increase *GDP*
National energy dependency	A decrease of import
shares of alternative fuel in transport	Increase share of alternative fuels and decrease import
Diversification	The more sources of fuels the higher Shannon-Wiener Index

4 Conclusion

There is a steady tendency of gradual growth in fossil fuel prices worldwide. This stimulates the search for acceptable alternatives. The alternative fuel management has been proved as an effective tool for improving energy security indicators. The motivations for starting its programs are the following: conventional fuel costs, environmental regulations, energy supply diversification, etc. The definition of alternative vehicle fuel management had been proposed.

The key findings from this study are as follows: biofuels are reducing greenhouse gas emissions and to improving energy security; petroleum fuels dominate on the transport and, therefore, energy security is currently equated with "crude oil security"; energy security indicators can be improved by increased use of indigenous fuel supplies and by implementation of the diversification strategy of supplies; alternative fuels could be used to supply the transport sector and contribute to improving the energy security indicators.

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