

USING OF ALTERNATIVE DRIVES IN A METALLURGICAL ENTERPRISE AND THEIR USING FROM THE POINT OF VIEW OF DEVELOPMENT OF THE METALLURGICAL ENTERPRISE'S PRODUCTION SCHEDULE

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Abstract

Possibilities of the use of alternative drives from the point of view of operation of an industrial enterprise are at present almost unlimited, and it will always depend on concrete conditions of the company to which measure the company will decide to use alternative fuels in its fleet. One of the main arguments for using of alternative motor fuels are ecological reasons. The aim of the paper was to perform environmental and economic analyses of possibilities of the use of alternative drives in the logistics of metallurgical enterprises, to evaluate the most beneficial fuel from this point of view, and to perform an analysis of obstacles of the following development of the alternative fuel, including proposal for their removal. The method of investigation was, first of all, analysis, synthesis and statistical evaluation of information which was obtained by studying of scientific papers, literature and legal documents at different levels of the state, EU and worldwide institutions. To find a reply to the question related to the impact of the fuels to the living environment, the Life Cycle Assessment analysis was used. According to the economic and ecological analysis, the paper evaluated CNG as one of the most beneficial alternative fuels; and the conclusion of the paper includes evaluation of obstacles of the following development of the CNG and a proposal of possibility of their removal. Besides of that, possibilities of expansion of the manufacturing enterprise's production schedule while using the expansion of CNG in the market as suitable fuel were specified in the conclusion. A solution of this theme fits into the conception of the circular economy, which is a conception which is an integral part of the sustainable development and dealing with the methods how to increase the quality of living environment and human life through increasing the production effectiveness.

Keywords: Alternative fuels, logistics of a metallurgical enterprise, Life Cycle Assessment, CNG, economic analysis, metallurgical enterprise's production schedule

1. INTRODUCTION

The paper proposes to perform environmental and economic analyses of possibilities of the use of alternative drives in the logistics of metallurgical and other industrial enterprises in after years, and also to perform an analysis of obstacles of the following development of the alternative fuel market in the Czech Republic and to propose possibilities of their removal. Another aim of the paper is also to propose possibilities of expansion of the metallurgical enterprise's production schedule in conditions of the growing use of alternative fuels in industrial enterprises in the Czech Republic.

The method of investigation used in the presented paper was a study of scientific papers, literature and legal documents at different levels of the state, EU and worldwide institutions as well as their analysis and synthesis of information. The question of alternative fuels has been very often solving at the present time from different points of view. The summary results of comparison of all types of the drives, however, are presented more likely peripherally and casually. That's why collection of sufficient quantity of relevant information for the resolved questions and their statistical evaluation with using of methods such as analysis, synthesis, induction and deduction will be especially used for the conclusions in the paper from the point of view of scientific

methods of investigation. To find a reply to the question related to the impact of the fuels to the living environment, we selected a simplified form of "well-to-wheels" type analyzing as the most suitable tool. It is a specific type of the LCA (Life Cycle Assessment) analysis, which is frequently used in relation to the evaluation of the impact of the fuels in the transport industry and different types of transportation or types of vehicles and their drives.

The use of alternative drives is more and more supported by governmental authorities as well as the European Union, which performs fundamental steps for the following development of alternative fuels in the European Union. With regards to giving-out of crude oil and enormous problems with the pollution of the living environment, the use of alternative drives is the only possible variant of the continuous development not only of road transportation. Considering a low price of alternative fuels, it is also a possibility how to reduce costs for the enterprise logistics, which create a big part of the overall operational costs. Fundamental issues, which are connected with the questions of alternative drives in the logistics of a metallurgical enterprise, are solving of problems of performance, durability, traffic distance and costs.

The storage of alternative fuels and their putting into vehicles, which must meet high safety-related requirements, plays an important role in the whole process of the user of alternative fuels. This is a task for metallurgical enterprises for which it can be a possibility of the next expansion of their production schedule [1].

2. THE USE OF ALTERNATIVE DRIVES IN A METALLURGICAL ENTERPRISE

Possibilities of the use of alternative drives from the point of view of the logistics of an industrial enterprise are at present almost unlimited, and it will always depend on concrete conditions of the company to which measure the company will decide to use alternative fuels in its fleet. While implementing, it is always necessary to go from whether it is external or internal transport (conveyance), road or railway transport or by means of other manipulation equipment.

While making a decision on the use of alternative drives in conditions of a company, it is necessary to consider these main factors:

- company's professional focus,
- company's area dimensions and a measure of manipulation with material or products inside the area,
- a necessity of transportation out of the company's area, a volume of conveyance and an average daily operational radius of the vehicles,
- composition and number of vehicles, their age and planned investments in acquisition of new vehicles,
- accessibility of alternative fuels, respectively of necessary energy sources and so on.

Separate technical and structural solutions of the vehicles with alternative drives and specifics of presently-used alternative fuels, respectively types of energies, are so different that it is very difficult to perform their general comparison and to say which from the alternative drives is the most beneficial. That's why it can be assumed that it will be more suitable to perform separate comparison from the point of view of two main reasons leading to the introduction of these new drives into the practice [2]:

- 1) The first one is endeavor to reduce or even absolutely eliminate impacts of the operation of the vehicles driving by classical fuels to the living environment, i.e. the ecological comparison,
- 2) and economic comparison on the other hand, which expresses an amount of costs for the travel of the selected distance unit or the entire costs of the vehicle operation.

Having evaluated these two aspects for the concrete conditions of an industrial company, the company then has to fit the creation of a particular model to the optimal select of the use of alternative fuels in conditions of the selected enterprise with respect to accessibility of the fuels and the price forecast with help of multicriteria methods depending on its concrete economical and technical criteria.

2.1. Ecological comparison

One of the main arguments for using of alternative motor fuels are ecological reasons. The impacts of the operation of the classical conceptions of vehicles to the atmosphere are at the present relatively well-known, including by their consequences to the human health and to ecosystems. As for alternative transport conceptions, their impacts within operation will be unequivocally lower, and in case of electromotors and fuel-elements are de-facto without emissions. A problem can be caused, however, by increasing of emissions while manufacturing separate conceptions or used-by-them fuels, and that is mainly with regards to the increase of technical demandingness of the production [3].

As for electric cars from the point of view of ecology, they produce no exhalations during their operation, that's why they do not burden the living environment in this life cycle. It is, however, necessary to consider methods of production of electric energy itself, methods of its behavior in automobiles in a form of big and heavy driving batteries; their manufacture means again a significant consumption of energies and mineral resources, their mining and processing with many risks and impacts to the living environment, and last but not least also, for example, methods of ecological liquidation of these batteries [4].

While using alternative fuels in the industrial transport depending on a chosen drive, zero emissions of harmful substances and other ecological impacts, it is necessary to proceed according to the valid methodology of LCA (Life-Cycle Assessment), then a method of evaluation of the life cycle, i.e. production of sources, manufacture of fuel, its distribution to consumers up to the phase of its consumption in a vehicle [5].

For searching replies to the questions of fuels and biofuels impact to the living environment, a simplified form of LCA called the "well-to-wheels" analysis is used as the most beneficial tool. It is a specific type of the LCA analysis, which is being frequently used in relation with the evaluation of the impacts of fuels in the transport industry and in different transport modes, eventually of types of vehicles and their drives. The analysis is divided into two basic parts. The first is WTT (Well to Tank), and the second is TTW (Tank to Wheels). The both parts include the whole life cycle, so called WTW (Well to Wheels). The first of them evaluates fuel from the mining of basic raw materials, through the whole processing chain, up to its delivery to a vehicle, respectively to transportation means. The second part evaluates the proper use of fuel. Impacts can be expressed in the relation to category of the impact of the global warming as equivalents of CO₂ [4].

Based on the analyses, it can be generally stated that the phase antecedent to the final consumption is very energy-demanding practically for all alternative motor fuels with the exception of CNG and LPG. The consumption of energy in the WTT phase in a better case corresponds to the own usable energy content of the alternative fuel (DME, synthetic liquid fuels, hydrogen produced from NG or biomass), in majority of the above-mentioned variants, however, energy content of fuel exceeds by 1.5-5-fold the consumed energy in the WTT phase (electrolytic hydrogen, bio-ethanol, bio-petroleum). As was proved, energy contained in biomass or natural resources is very low concentrated, and bigger part of the usable energy potential of the renewable resources has to be reserved for the production of alternative fuels, and it will not be possible to use in the phase of final consumption. In practice, energy from non-renewable resources is more or less consumed for the production of any type of alternative fuel. It is mostly electric energy and motor fuels in the agriculture and transportation [6]. Energy from non-renewable resources is more or less consumed in production of almost each type of alternative fuel. Predominantly it is electric energy, and motor fuels is used in the agriculture and transportation. That's why there is objective only a complex analysis, which enables consideration of the fact that the production phase in some cases can so ecologically and energetically demanding that the positive effect in the general balance of the final consumption of fuel in vehicle (for example, hydrogen) is absolutely negated. The complex evaluation of the influence of fuel to the living environment (LCA) at the present is globally a subject of activity of a series of research workplaces. It is the questions significantly complicated, requiring analysis of a big amount of very different input data from among the branches of the national economy (agriculture, raw materials mining, energetics, chemical industry, automotive industry, economics) [5].

The total WTW emissions of greenhouse gases while using CNG as motor fuel relative to the usable energy content are lower than the corresponding emissions of automobile gasoline and diesel oil. In case of inclusion of the total balance of energy and GHG emissions of natural gas, the riskiest factor is the distance between the localities. At present, the average conveyance of a gas main in EU fluctuates about 4,000 km from the Near East and it is expected its extension up to 7,000 km from Siberia in the future.

In case of LPG, the decrease of GHG emissions is minimal compared with gasoline and diesel oil, it however more significantly contributes to the decrease of hazard pollutants; all the more difference is in older fleets. The LPG sources are bound with the crude oil resources, that's why it is middle-term horizon fuel. Its accessibility in the market, however, is problem-free [7].

It can be stated that emissions of the basic harmful substances in case of the combustion of alternative fuels are generally significantly more favorable than emissions originating during combustion of conventional automobile gasolines and diesel oil. The automotive industry had to react to gradual strengthening of the emission limits, and that is by developing and modification of the structure of the driving units and systems for consequential modification of the composition of exhaust fumes. It after all manifested itself positively also by decreasing emissions of some, earlier problematic, pollutants in exhausted fumes while using alternative fuels, for example, total hydrocarbons in case of the CNG gas motors or NO_x emissions in case of combustion of mixed diesel oil or biodiesel. Based on the comparison of the emission factors typical for liquid (bioethanol, biodiesel) and gaseous (CNG, LPG) alternative motor fuels, gaseous fuels are clearly more beneficial. While using vehicles of higher emission categories, i.e. at least of EURO 4, equipped with modern effective systems for the check and control of the combustion process and modification of the exhaust fume quality, differences between separate types of the fuels are partially eliminated [5].

Relatively higher emissions of hydrocarbons in the case of vehicles with a CNG drive mainly consist of residual non-combusted methane provided only non-methane emissions of hydrocarbons (NMHC) are evaluated, i.e. emissions of higher and riskier for the health hydrocarbons, then the operation of CNG vehicles in this comparison appears as even more ecologically beneficial [8]. The only problematic harmful substance can be volatile aldehydes, their degradation on effective catalytical convertors of exhaust fumes, however, is in general simpler than of hydrocarbons themselves, by which partial oxidation within the combustion process they originate. The use of alternative gaseous fuels is also significant from the point of view of the indispensable decrease of health riskiness of emissions produced by the fleet of older date of production, often without presence of catalysts of exhaust fumes. The reparation of conventional motor fuels by alternative driving substances also means a big contribution from the point of view of the decrease of the potential creation of photo-oxidative smog and low-level ozone, which is beneficial especially in municipal agglomerations strongly loaded by transport [5].

Alternative gaseous and liquid fuels in consumption with classical driving substances based on oil - automobile gasoline and diesel oil in general in the final phase of their consumption in vehicle (TTW) represent a lower load for the atmosphere both from the point of view of greenhouse gases (GHG) emissions and other inorganic and organic harmful substances contained in exhaust fumes of combustion engines - carbon monoxide (CO), nitrogen oxides (NO_x), total hydrocarbons (HC), particles (PM) and minority organic compounds with a high risk potential (polyaromatic hydrocarbons, aldehydes, alkenes). The benefit of alternative gaseous fuels is the fact that they form no load for water resources and soil [5]. Based on the above-mentioned evaluations, it can be stated that CNG is a very suitable alternative for the use as driving fuel.

2.2. Economic comparison

The general economy has a decisive role in the development of the use of alternative fuels in the transport; it means both the return rate of investment and operational demandingness of vehicles as well as the economics of fuel stations.

The crude oil price as a strategic raw material is the decisive factor also for the prices of other fuels and energies. A similar price development of these commodities is a result of the historical linkage of alternative fuels to the prices of oil products. This linkage was, of course, additionally formed by basic economic relationships such as mutual competitiveness or the supply-and-demand law. The prices of motor fuels result from the price of crude oil, development of the CZK/€/USD currency exchange, as well as seasonal influences can be registered (summer touristic season). The crude oil price can be predicted very generally with regards to the decreasing oil reserves and partially with regards to the growing demand of the fast-developing economies of China and India. The fundamental influence to the crude oil price can have worldwide political crises and war conflicts; these situations, however, cannot be predicted at all. On the basis of the analysis of data of the long-term development of the crude oil prices, motor fuel prices and the USD rate, a dependence with average and relatively high correlation coefficient can be created. Better results can be achieved by correlation of prices of the crude oil prices with a month delay towards the price of motor fuels. Considering the price of fuels, it is necessary to take into consideration a margin of fuel stations which fluctuates at present in an interval of 1.5 - 2.0 CZK/l [3]. **Table 1** specifies average annual prices of gasoline, diesel oil and CNG, which from the point of view appear as very suitable alternative fuel. Also, from the point of view of the price, where 1 liter of gasoline or diesel oil corresponds to 1 m³ of the consumption of CNG, the prices of natural gas are lower by half.

Table 1 Annual average prices: CNG - gasoline - diesel oil in Czech Republic [9]

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CNG (CZK/m³)	15.9	15.75	16.46	16.7	16.95	17.19	18.1	18.39	17.69	17.25
Gasoline (CZK/l)	28.27	31.53	31.74	31.57	33.65	36.21	36.5	31.42	28.75	30.39
Diesel oil (CZK/l)	24.72	26.67	30.57	34.25	36.53	35.91	36.15	30.75	27.08	29.57

One more fact which will significantly influence the return rate of the future investment is the purchasing price of the vehicle or a difference between the vehicle with a classic drive and the vehicle with an alternative drive. A reconstruction of the vehicle from so called classical fuels to CNG costs in average of 60,000 CZK. A more beneficial solution can be purchasing of a new vehicle with CNG technology.

Prices of service works also directly are related to the used technology of the drive, where we can presume different price per norm-hour of work according to demandingness of the performed works and also, for example, according to the requirements for professionalism of a service engineer in accordance with regulations of the producer or valid standards and laws.

Together with the fuel price, respectively energy necessary for the vehicle operation depending on the selected driving unit, the purchasing price of the vehicle and costs for service and spare parts, a series of other factors can also interfere to the resulting costs. Probability the most important factor is willingness and possibilities of the state to participate in using of alternative fuels in the operation of motor cars, and, of course, an amount of such a support.

The most favorable alternative drive in the Czech Republic is LPG. A benefit of CNG compared with LPG is a non-decreasing motor power, higher safety, minimum pollution rate of the atmosphere, low service costs and better compatibility with modern forced induction engines. In case of CNG vehicles, which sells directly automobile manufacturer, a baggage space is not reduced since the tank is placed directly under the floor of the trunk. The biggest problem of CNG is a sporadic network of fuel stations. This network, however, is gradually expanded.

In case of big companies, among which the metallurgical enterprise can be sure ranked, the costs of purchasing of transportation means or their leasing, as well as consequential purchase of energies necessary for their operation, are a significant part of the cost side of the budget. Although now it is very difficult or even impossible to predict the development of the classic fossil fuels prices (automobile gasoline and diesel oil) in the worldwide markets, it is relatively clear that at the actual prices of natural gas, which are long-term relatively invariable, the use of CNG or LNG as a fuel of the transportation means is suitable both from the point of view of ecology and also economy.

In case of a metallurgical enterprise, possibilities of the use of natural gas in the transportation according to the used transportation means are very wide. CNG or LNG is used in the operation of passenger cars and light utility vehicles, trucks and also vehicles for internal transport, especially fork-lift carriages and manipulation carriages as well as other special transportation means. An interesting possibility of CNG usage, which is not said a lot about, is the operation of locomotives [10].

2.3. Potential for the production schedule in metallurgy and machine engineering

The development of the use of alternative fuels in the transport can bring significant changes in a metallurgical enterprise both in the development of the production schedule and in applications of new technologies within the operation of the enterprise, in the given case in the transport system, which can also have a significant influence on the ecology.

Pressure vessels, which must meet high safety standards, are used in the entire process of the use of natural gas in the transport, i.e. from storage and transportation up to putting into transportation means. In the case of a metallurgical enterprise, it can be just production of pressure vessels and pipes with a possibility of further expansion of the production schedule. It is unequivocally given by that the production of the pressure vessels is, thus, the first and basic possibility leading to the next growth of the metallurgical enterprise in relation with the use of CNG in the transport. Pressure vessels can be divided at least into three groups depending on the structure, operational pressure, outside diameter, length and capacity (so called the water volume):

- 1) for the integration into passenger cars delivered directly to the automotive factories or for individual reconstructions,
- 2) for the integration into trucks, buses and other big transportation means (for example, locomotives),
- 3) for transport and storage of CNG (LNG).

The second significant sphere of other possible growing of the metallurgical enterprise or the expansion of its production schedule is integrally connected with the proper operation of vehicles equipped with a CNG drive. It is, thus, part of distribution, storing and filling of pressure vessels of the transportation means with natural gases. Practically it means as follows:

- production of stationary or mobile gaseous reservoirs and containers,
- production of trailer-type gaseous reservoirs,
- building of filling stations.

A suitable additional production schedule of the enterprise can also be a reconstruction of vehicles to the CNG drive, production of kits for the reconstruction to CNG and provision of service related to it, including carrying-out of revisions of the pressure vessels, or building and also running of public CNG filling stations.

3. CONCLUSION - CNG AS THE BEST FUEL

With regards to the stable price of gas and its expected surplus (USA newly in the position of a gas exporter), CNG is the only possible alternative how quickly and cheaply reduce costs for fuels, and at the same time to meet requirements of the EU for the reduction of emission of CO₂ and other polluting substances. CNG, thus, offers at the present time a unique possibility how to enforce the competitiveness of the enterprise.

CNG (abbreviation for Compressed Natural Gas) (chem. composition - 98 % of methane) appeared as the most suitable fuel, because:

- From the ecological point of view - CNG vehicles don't produce dust particles (PM10), there are significantly lower emissions of nitrogen oxide, sulphur oxide and especially carbon dioxide (CO₂ by 25 % to 35 %), there is no threat of soil contamination, roads and garages, and besides of that a significant limitation of produced of waste products contributes to the protection of the atmosphere.
- From the economic point of view - vehicles with NG drives cause substantial savings per 1 km (up to 30 - 50 %) and, in addition, natural gas as fuel is practically impossible to steal (prevention from leakage from the system). There is a sufficient number of long-term natural gas fields in the world. An important option is also a possibility of its obtaining from biogas.
- From the safety point of view - CNG is the safest fuel, it is saved in thick-walled pressure vessels; all CNG reservoirs have safety locks of gas leakage, it has high ignition temperature compared with other fuels, and besides of that, it is freely dispersed; there is no threat of contamination of soil, garages, etc.

According to the Green Book (EU), CNG has to achieve of a 10 % share of the fuels till 2020, which corresponds to a value of 215 mil. kg/year. Considering the actual trend, the sales of CNG would achieve just 33 mil. kg/year till 2020.

Big industrial enterprises are obliged to invest tens of billions of Czech crowns annually in ecological measures, and their share in the pollution of the atmosphere has been fundamentally decreasing. The share of emissions from the transport continues to grow, and the taken measures is not enough. CNG offers fast, effective and unpretentious solution in the sphere of transportation. For many years the CNG-driven vehicles meet the EURO 6 emission standard, which became effective in September 2014.

The reason of time-consuming development of the gas usage in the transport is existence of a series of obstacles. One of the main obstacles of the development of the natural gas usage in the transport is an insufficient infrastructure of gas filling stations for CNG compared with the dense network of filling station for classic fuels. The support of CNG should be especially focused on the creation of optimal conditions, which will not be limited by absence of a network of filling stations. A voluntary agreement between the government of the Czech Republic and the gas industry about a share of the gas industry in the construction of the network for natural gas should be concluded.

Another obstacle for a big expansion of the gas usage in transportation means are higher investment costs related to the purchase of a CNG-driven vehicle compared with a vehicle driven by diesel oil. To improve this situation, the state could create conditions, both within the subsidy programs and tax allowances, which would motivate both citizens and enterprises to buy ecological transportation means.

Another significant obstacle is uncertainty of the trend in prices of natural gas as motor fuel. The removal of this obstacle consists in long-term stabilization of the consumption tax for the use of CNG in the transport. In this regard it is necessary to note that the growth of the crude oil price can be one of the considerable stimuli determining the transition to CNG and increasing the use of natural gas in the transport. Another aims of the CNG progress should focus on filling of "white places", on the construction of GNG stations in new localities and their placement on refuges together with usual fuels, on changing of standards for parking of CNG-driven vehicles in underground garages and also on de-demonization of CNG as dangerous fuel [11].

A solution of the theme specified in the text of this paper fits into the conception of the circular economy, which is a conception which is an integral part of the sustainable development and dealing with the methods how to increase the quality of living environment and human life through increasing the production effectiveness. Considering this concept, it is an endeavor to exclude origination of non-recyclable waste both on the end of the chain and during the production process, for example, combustion products originated during transportation. That's why the use of alternative fuels in the industrial transport can have a big importance for the concept of the circular economy. It is because the development of the use of alternative fuels in the

transport can bring significant changes in a metallurgical enterprise both in the development of the production schedule and in applications of new technologies within the operation of the enterprise, in the given case in the transport system, which can also have a significant influence on the ecology.

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