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RESEARCH ARTICLE

# Estimation method for determining the environmental impact of biofuel blends

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***Abstract***

*The operation of vehicles causes damage to the environment through combusting fuels. Increasing motorisation and traffic results in an increased environmental impact, and the caused effects can be experienced locally and globally. The only solution that decreases environmental load without restricting mobility is the application of new environment friendly energy sources, which can be used and stored safely and which can be produced and applied in an environment friendly way. While trying to adapt to the changes caused by environment pollution the society and the people, who participate in transport need to modify their approach. The development of an environment conscious lifestyle in order to preserve the living-space of future generations is a common interest of all of us. The aim of this paper is the upper estimation of the environmental impact deriving from fossil and biofuel consumption in the case of diesel oil and gasoline driven motor vehicles.*

***Keywords***

*gasoline · diesel · ethanol · biodiesel · environmental impact*

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## 1 Introduction

The change of the environment and the human actions, which influence it are linked to the society and economy. Transport has to hold on in a space defined by the natural, economical and sociological environment in a way that it satisfies the mobility needs of the society by being environment friendly and effective in an economical point of view. The explosive scientific and technical development of the last century gave such tools and technical solutions to people, which might have an increasing effect on the environment. Meeting the requirements of increasing customer demand causes damage to the environment, but at the same time the reduction of environment pollution is essential for survival. The needed solution is based on technical development, on material optimized technology, on the application of renewable energy sources and on environment friendly transport and transportation. Due to the size (and inertia) of the Earth the pollutants emitted in the past would even modify our future environment if the emission stopped immediately.

The reduction of environmental load and the minimizing of pollutant emissions deriving from the development and maintenance of road transport infrastructure is a justifiable demand of the society. As a consequence of environment pollution deriving from transport the climate of the Earth changes, which has an effect on the state of society and economy. A significant part of environment pollution derives from transport. Road transport is the main contributor to environment pollution within the transport sector. Changes caused by environment pollution and environmental anomalies react transport. The aim of this paper is to make an upper estimation of the environmental impact deriving from fuel consumption of diesel oil and gasoline driven vehicles.

## 2 Introduction of the theoretical estimation method

Motorization has been developing so dynamically that air, soil and water pollutions became considerable to the amounts of air, soil and water of the Earth (see Fig. 1). Sustainable development refers to a development which has to balance between technical development, satisfaction of increasing customer demand and use of resources in such a way, that the possibilities, living con-

ditions and standard of living of future generations will not be worse than that of the present generations [9]. Although there are other gases emitted by people, which are as well responsible for climate change, in our study just $CO_2$ emissions are taken into account, because of their share and their relation to transport.

The base of the presented estimation method is the assumption that during the ideal combustion of the fuel the fuel's carbon content burns to $CO_2$ (1), its hydrogen content burns to $H_2O$ (2) and its oxygen content feeds the combustion. In reality ideal combustion cannot be performed, therefore just less $CO_2$ can be produced in the engine, so it is an upper estimation [1, 3, 8].

$$C + O_2 \rightarrow CO_2 \tag{1}$$

$$2H_2 + O_2 \rightarrow 2H_2O \tag{2}$$

Our task was the determination of the carbon, hydrogen and oxygen content of gasoline-ethanol and diesel oil-ethanol-biodiesel blends respectively [2, 8]. Therefore firstly the density of the blends had to be calculated (3) and after knowing the density, the carbon, hydrogen and oxygen contents were calculated.

$$\rho_{mix} = \sum_{i=1}^{n} V_{V/V\%,i} \cdot \rho_i, \tag{3}$$

where:

$\rho_{mix}$: density of the blend [g/cm$^3$]
$V_{\%/\%,i}$: volume percentage of component i [V/V%]
$\rho_i$: density of component i [g/cm$^3$]

$$A_{mix} = \frac{\sum_{i=1}^{n} V_{V/V\%,i} \cdot \rho_i \cdot A_i}{\rho_{mix}} = \frac{\sum_{i=1}^{n} V_{V/V\%,i} \cdot \rho_i \cdot A_i}{V_{V/V\%,i} \cdot \rho_i}, \tag{4}$$

where:

$A_{mix}$: mass percentage of given atoms in the blend [m/m%]
$A_i$: mass percentage of given atoms in component i [m/m%])

Oxygen requirement and carbon dioxide emission of fuel blends were estimated with the theoretical model assuming ideal combustion. In our calculations we assumed that during the ideal combustion the oxygen is captured from the atmosphere, thus decreasing the oxygen content of the atmosphere. During the ideal combustion the fuel burns to carbon dioxide and $H_2O$, and former contributes to green house gas emission, since it is a green house gas. In our model the environmental impact is characterized by the oxygen needed for the combustion and by the $CO_2$ and $H_2O$ production.

$$\kappa = \phi_{O_2} + \varepsilon_{CO_2} + \varepsilon_{H_2O}, \tag{5}$$

where

$\kappa$ : cumulative environmental impact [m$^3$][1]1
$\phi_{O_2}$ : Oxygen requirement of the fuel blend for ideal combustion [m$^3$][2]1,
$\varepsilon_{CO_2}$ : $CO_2$ production of the fuel blend assuming ideal combustion [m$^3$][3]1
$\varepsilon_{H_2O}$ : $H_2O$ production of the fuel blend assuming ideal combustion [m$^3$][4]1

## 3 Results

In our paper the term environmental impact refers to the stoichiometric oxygen requirement needed for the combustion and the $CO_2$ and $H_2O$ production respectively. First we applied our model for examining the environmental impact of a spark ignition internal combustion engine. Ethanol was added stepwise (5%) to gasoline (see Fig. 2). The blend was marked by E0-E100 signs according to the ethanol content. As it can be seen in Fig. 2 the added ethanol theoretically reduces the cumulative environmental impact, because the oxygen content of the added ethanol reduces the oxygen requirement of gasoline and less $CO_2$ is produced.

It has to be mentioned though, that ethanol has a smaller lower heating value, which results in increased fuel consumption at similar power requirement. According to some studies [4–6, 8] the rate of consumption change is smaller than that is theoretically expected from the difference in lower heating values and densities. Some references confirm that increased fuel consumption should be taken into account, the rate of which is in the case of adding 5vol% ethanol 2% performance decrease on the average in place of the theoretical 1,7%. The modified, increased environmental impact is characterized with the corrected environmental impact curve (see Fig. 2). We did not take into account the renewable part of the carbon-dioxide emission, because it has been already mitigated from the atmosphere. Our concept was to make an upper estimation of prompt environmental impact of biofuel blends in spark ignition internal combustion engine.

Secondly the environmental impact of internal combustion diesel engines was examined (see Fig. 3). The emissions of diesel oil (D) – ethanol (E) – biodiesel (B) blends were examined. As it can be seen in Fig. 3 the ethanol and biodiesel added to diesel oil reduces the environmental impact. Fig. 3 shows clearly that biodiesel causes a smaller increase in fuel consumption (because of its higher lower heating value) moreover it provides the combustion with plus oxygen (more oxygen is provided than with the addition of ethanol).

It has to be mentioned though that the lower heating values of biodiesel and diesel oil are quite equal, but the lower heating value of ethanol is smaller than that of diesel oil, which causes an increase in fuel consumption at similar power requirement. The increased environmental impact (modified with the increase in consumption) is characterized by the corrected environmental impact curve (see Fig. 3). We did not take into account the renewable part of the carbon-dioxide emission, because it has

[1] At 1 bar atmospheric pressure and 293K temperature.

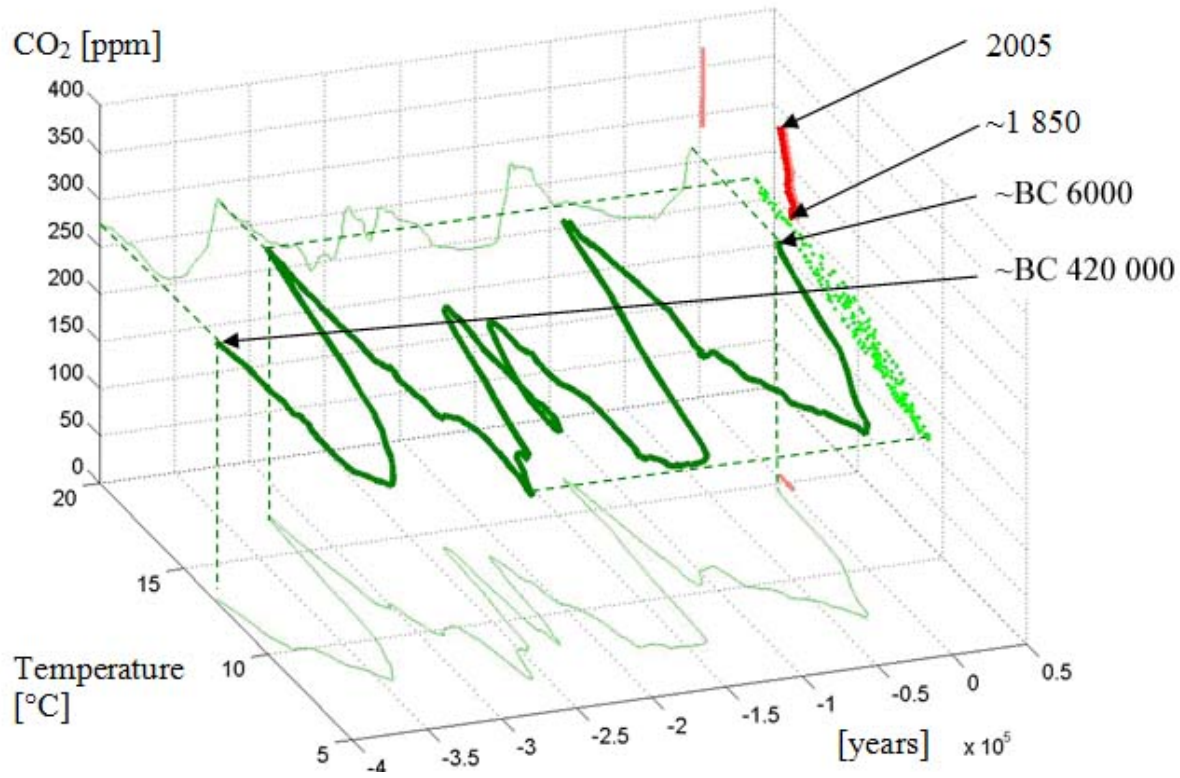


**Fig. 1.** Average atmospherical $CO_2$ and average Earth temperature complex time series [7]

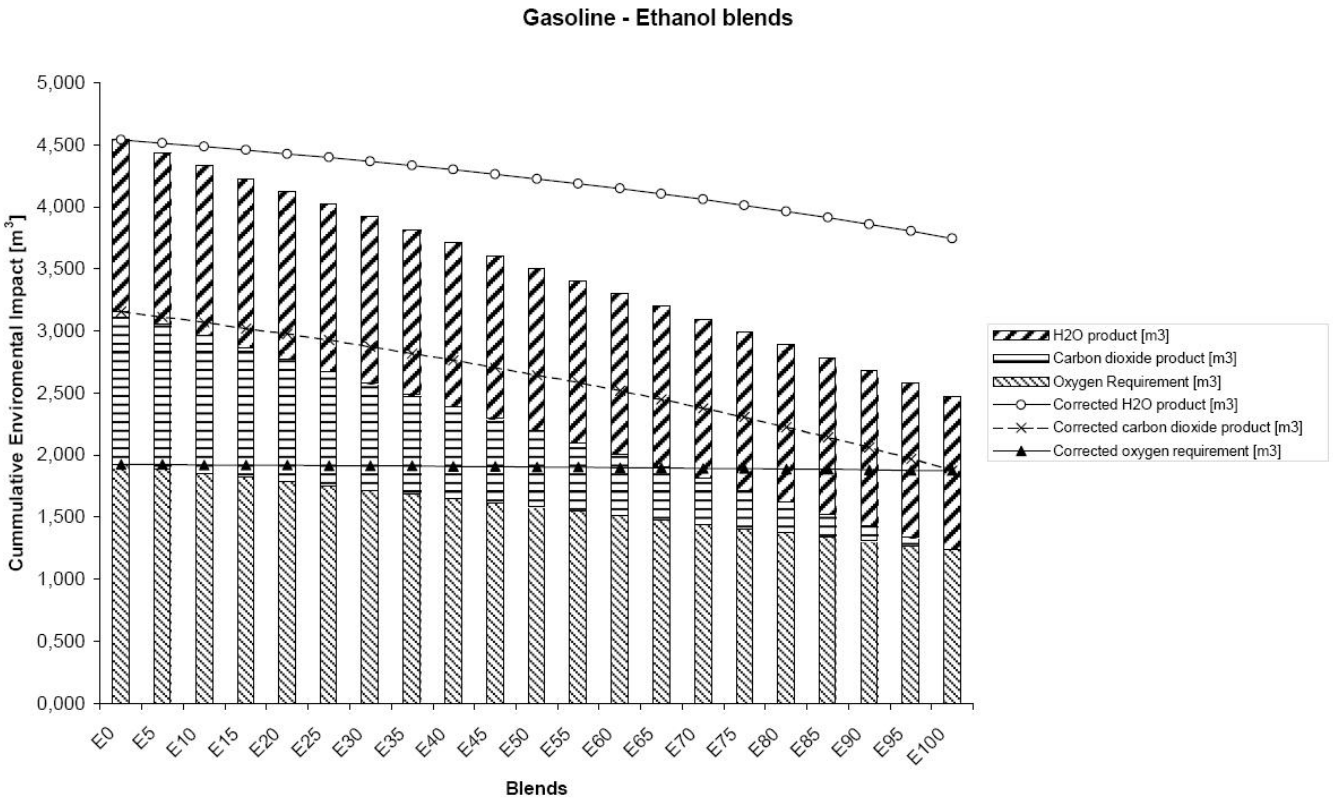


**Fig. 2.** Estimated environmental impact of ethanol-gasoline blends

been already mitigated from the atmosphere. Our concept was to make an upper estimation of prompt environmental impact of biofuel blends in internal combustion diesel engine.

## 4 Summary

Fossil fuels are burnt in vehicles. If ideal combustion existed, only $CO_2$ and $H_2O$ would be produced. Carbon dioxide causes increased green house gas effect and global warming (see

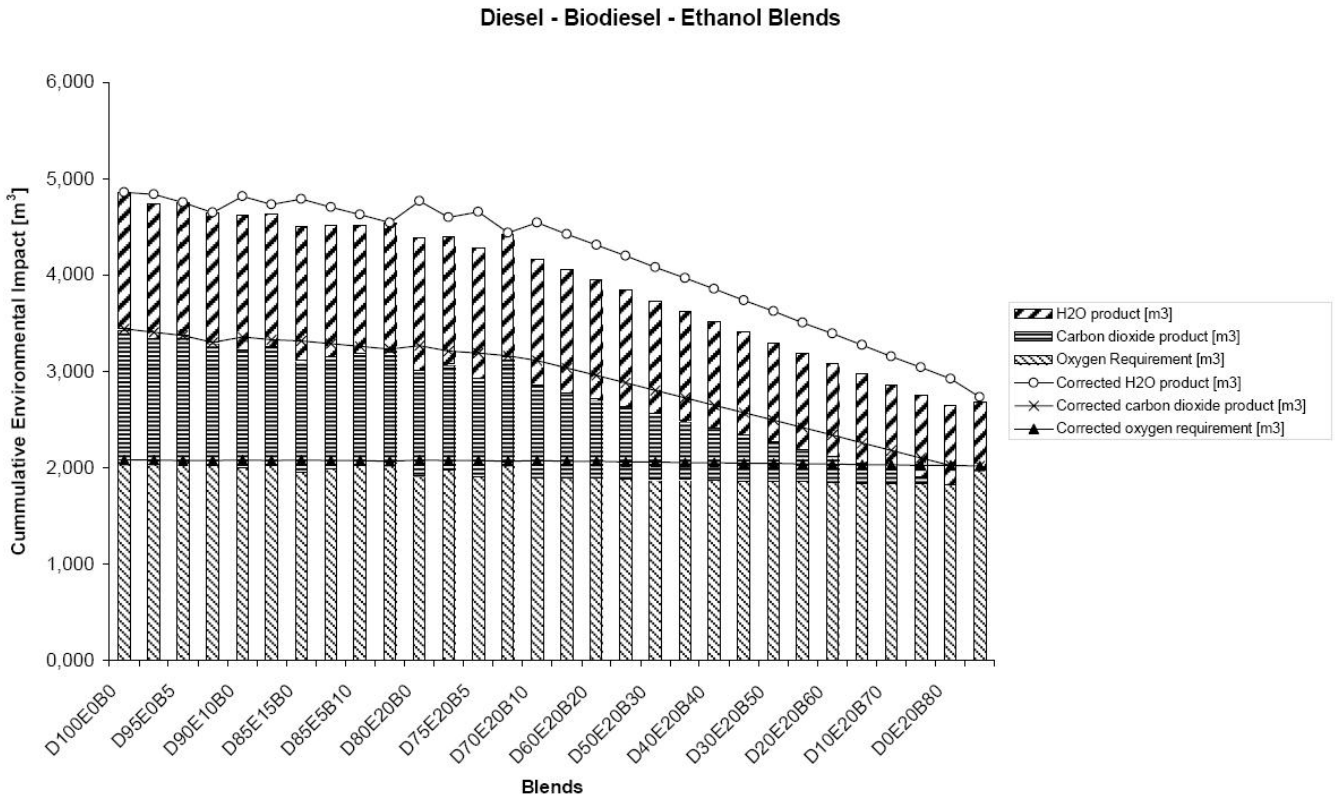


**Fig. 3.** Environmental impact of diesel oil- biodiesel-ethanol blend

Fig. 1). The reduction of $CO_2$ emissions can just be achieved by decreasing the amount of fuels burnt and by enhancing drains respectively. One solution could be the application of fuels with no carbon content (e.g. hydrogen). The use of fuels with lower carbon content is not expedient due to the fact that in that case only the place of the emission would change; the environment pollution would occur during the fuel production instead of the operation of the vehicle. Another solution is the reduction of the amount of burnt fuels, which could be urged with the tools of transport management (e.g.: influencing car ownership, vehicle application, driving behaviour regulations). Unfortunately the reduction of global environment pollution can just be achieved globally as a result of social cooperation. In the case of making such significant decisions it is always difficult to define the responsible parties and to force them to act. It has to be mentioned that not only those strategies should be preferred which aim the increase in effectiveness (e.g.: favouring vehicles with lower fuel consumption) but also sufficiency strategies should be reinforced (e.g.: reduction of individual car use) [9].

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