

ENVIRONMENTAL IMPACT OF BIOFUEL BLENDS — THEORETICAL ESTIMATION

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ABSTRACT - It is a well known fact that climate change is one of the most urging problems nowadays. There is evidence that most of the observed global warming is attributable to human activities. Among the many human activities transportation plays a considerable role in contributing to CO₂ emissions. In the future transportation is projected to grow further on and since other energy consuming sectors are unable to compensate for transportation related emissions, therefore the transportation sector has to contribute to emissions abatement. Using environment friendly energy resources is the only way to reduce environmental load without restricting mobility. One way to decrease CO₂ emissions of the transportation sector is the application of biofuels. The aim of this paper is the theoretical estimation of the environmental impact of ethanol—gasoline and diesel oil—ethanol—biodiesel blends respectively.

INTRODUCTION

In the last few thousand years nature gave humanity a stable base of living and gave almost infinite supply to reserve the biosphere. In early ages humanity made changes to the environment with limited technology, but the rate was infinitesimal compared to the size of the natural environment. Global changes were not detected.

In the last two or three hundred years there was an explosion in the development of the industrial and technical sector, which gave people a multiplied set of tools to encroach on nature. 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.

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but in the indefinite future, or in other terms it is a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". (1) (2)

Transportation cannot be replaced because it is the part of the production chain. Societies are horizontally and vertically differential, therefore manpower, stocks, semi finished and finished products must be transported.

The importance of the transportation sector is indicated by the sector's production which is 10% of the GDP of the European Union and more than 10 million people are working in this sector. One of the most emphasized goals of the European Union's transport policy is sustainable mobility. Trends in almost all sectors of the economy will affect the transport sector. In other words, growth in economy leads automatically to growth in transport.

Economic growth cannot exist without the availability of transport. The role of the economy has always been the production and distribution of wealth. To attain that goal the existence of transportation is indispensable, because it permits an intensification and internationalization of the exchange of goods and services. At the moment it is not possible to decouple economic growth from growth in road transport. However, and more importantly, it is possible to

decouple growth in road transport from its environmental impact. For this reason transportation systems must be developed and standardized, the effectiveness of transportation service must be increased, while environmental pollution must be decreased or prevented. One way to tackle this challenge could be the use of biofuel mixtures.

THEORETICAL ESTIMATION OF ENVIRONMENTAL IMPACT

Nowadays, human impact is considerable from the point of view of the atmosphere. CO₂ emissions caused by humans raise global temperature. More than 25 % of total CO₂ emissions caused by humans is produced by road transportation, so road transportation contributes to climate change. The contribution of road transportation to climate change is depicted on Figure 1. Within the transport sector, road transport's market share is the largest and it is increasing due to its superior service, in terms of greater flexibility, reliability, speed and lower probability of damage.

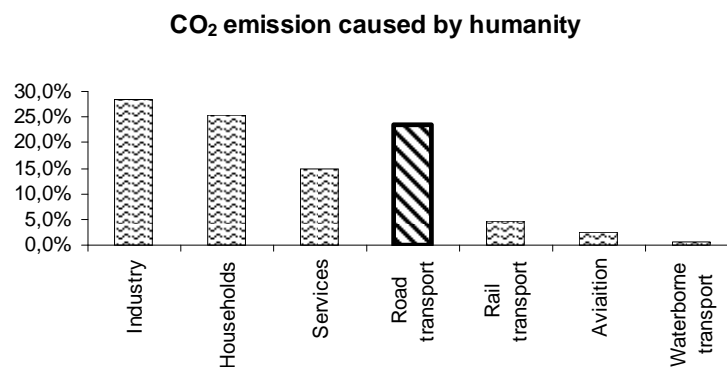


Figure 1: The contribution of road transportation to climate change (3)

There is a common, social will to protect Earth and environment. As it is depicted on Figure 2, as a consequence of human activity CO₂ concentrations have dramatically changed. Global warming is often characterized by the expected global mean temperature increase associated with certain atmospheric concentration of greenhouse gases. Effects, though, are ranging more wide, with the actual temperature rise varying according to seasons, the time of day, and across regions. Increased evapotranspiration (a term used to describe the sum of evaporation and plant transpiration from the surface to the atmosphere) is expected to lead to mean increase in precipitation, again with an actual impact varying in space and time. Beyond this, accurate predictions are difficult. However, it is generally accepted that there will be an increase in extreme weather events. In addition there is a small but real risk of unpleasant surprises.

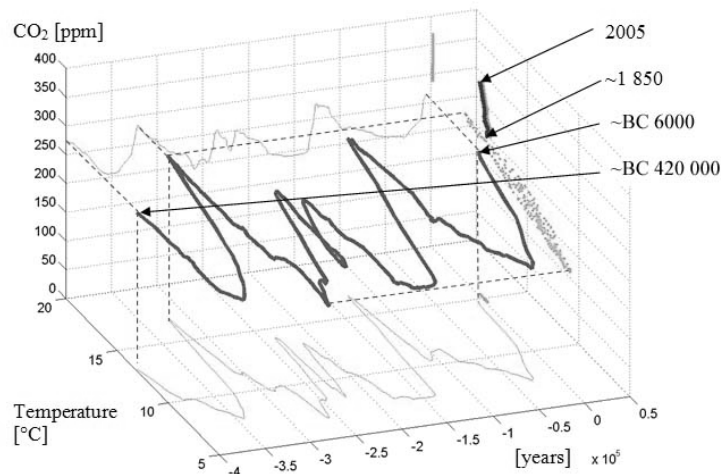
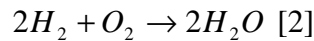
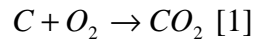


Figure 2: Average atmospheric CO₂ and average Earth temperature complex time series (4)

It is not desirable to simply ignore low probability events, without taking their costs into consideration. The view that small probability events would have a negligible impact on expected cost calculation is only correct if probability falls faster than cost rises. There is a strong connection between environment and road transportation. Road transportation has an effect on the environment by emitting pollutants and greenhouse gases, but environment has also an effect on road transportation through climate change. From this point of view transportation has to balance in this dynamic space. Transport plays a significant role in economic development. Efficient transport systems, both of people and goods, enable an economy to develop an optimal allocation of scarce resources, thus maximising wealth. The road transport sector is well aware of this essential economic role and of its social responsibilities, road safety, labour conditions, environment, energy saving and consequently sustainable development. It has to fulfil the challenge of environment, society and economy. When developing a policy for transport this “sandwich” position of the sector should be kept in mind constantly. The main contribution from transport to climate change is caused by CO₂ emissions. Carbon dioxide emissions are one of the agents responsible for global warming. The volume of CO₂ emission in the transport sector is directly related to the volume of road traffic and the fuel consumption ratings of individual vehicles. Great strides have been made towards making vehicles more fuel efficient, but the progress in this area has been slowing down as a result of increased weight (because of safety) and higher average power of vehicles now on the roads. Rising levels of car ownership in certain countries – which still lag far behind those of the wealthiest countries – suggest that the impact of transport on global warming will remain a major problem. Fuel charge is a good instrument for internalizing the costs of climate change. For this reason there is a need for the estimation of CO₂ emissions of fossil and renewable fuels, and their mixtures. Our estimation method is presented hereinafter.

The base of the presented estimation method is the assumption of ideal combustion, although it is clear that in reality ideal combustion technically cannot be performed (5). The term environmental impact in this paper means the sum of carbon dioxide emission and oxygen requirement of the fuel blends. In our estimation model we have modelled the ideal combustion of gasoline, diesel oil, ethanol, biodiesel by the carbon, hydrogen and oxygen content hereinafter. The carbon content burns to carbon dioxide, the hydrogen content burns to water and the oxygen content provides extra oxygen to the burning (see equation 1 and 2):



In this model firstly we theoretically determined the density of the mixture knowing the density of gasoline, ethanol, diesel oil, biodiesel (see equation 3). Secondly we determined the carbon, hydrogen and oxygen content of the mixture.

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

Where:

ρ_{mix} : density of the mixture [g/cm³]

$V_{V/V\%,i}$: volume percentage of component i. [V/V%]

ρ_i : density of component i. [g/cm³]

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

Where:

A_{mix} : mass percentage of given atoms in mixture [m/m%]

A_i : mass percentage of given atoms in component i. [m/m%]

As we knew the mass of the mixture we calculated the mass of given atoms in the mixture with equation 4. With equations 1, 2 and 5 we calculated the oxygen requirement and carbon dioxide production of each mixture. The ideal gas law was applied to convert the mass of oxygen and carbon dioxide to volume. An ideal gas is defined as one in which all collisions between atoms or molecules are perfectly elastic and in which there are no intermolecular attractive forces. In such a gas, all the internal energy is in the form of kinetic energy and any change in internal energy is accompanied by a change in temperature. An ideal gas can be characterized by three state variables: absolute pressure (P), volume (V), and absolute temperature (T). The relationship between them could be deduced from the kinetic theory and is called the ideal gas law:

$$P \cdot V = n \cdot R \cdot T \quad [5]$$

Where:

n = number of moles

R = universal gas constant = 8.3145 [J/mol K]

One mole of an ideal gas at standard temperature and pressure (standard temperature: 0°C = 273.15 K, standard pressure = 1 atmosphere = 760 mmHg = 101.3 kPa) occupies 22.4 litres.

CORRECTION WITH THE LOWER HEATING VALUE

Although the relative environmental impact of biofuels is less, because of the extra oxygen added to the burning by the biofuel, the lower heating value has to be taken into account too. Technically ethanol has a smaller lower heating value compared to gasoline, and biodiesel has nearly the same of dieseloil. If the same power demand is assumed, then the increasing fuel consumption should be taken into consideration.

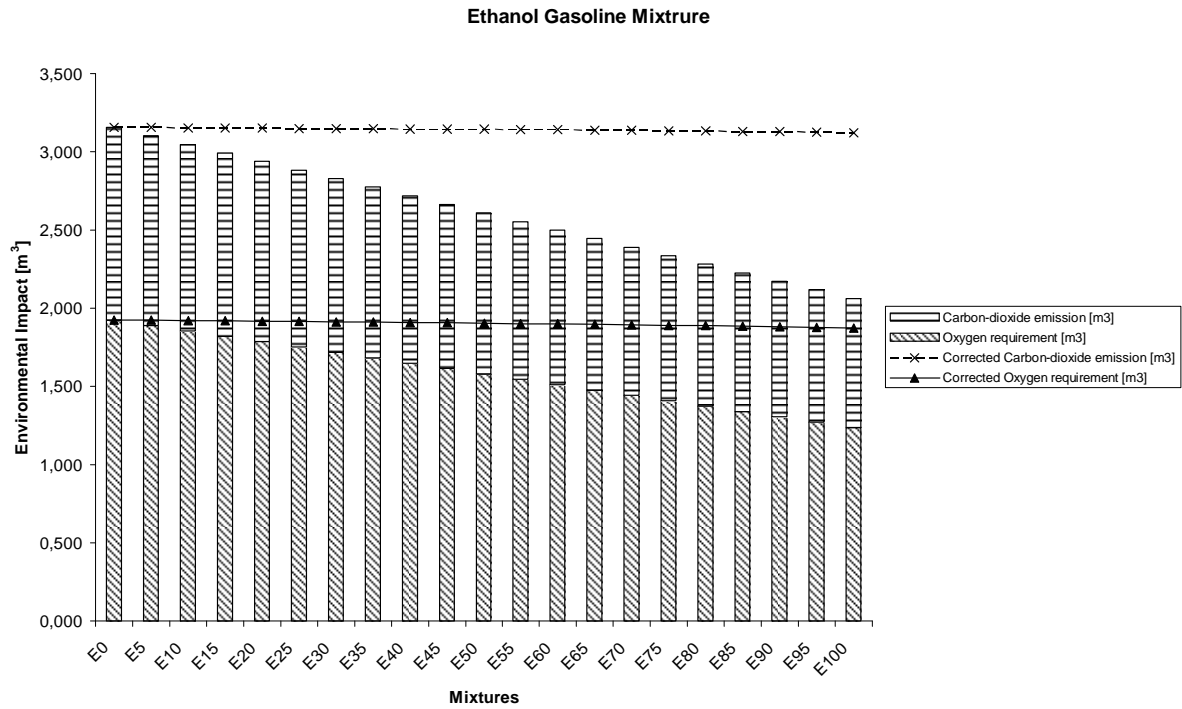


Figure 3: Environmental impact of ethanol-gasoline mixture

In Figure 3 the x-axis shows the examined gasoline-ethanol blends. The number after “E” refers to the ethanol content (in percentage). E0 refers to a pure gasoline and E100 refers to a pure ethanol mixture. On the y-axis the environmental impact can be seen without and corrected with the lower heating value. As it can be seen in Figure 3 the corrected environmental impacts of ethanol-gasoline mixtures are nearly equal to the environmental impact of gasoline. This means that the relative lower environmental impact corrected with the increasing consumption (derived from the lower heating value) leads to nearly the same environmental impact.

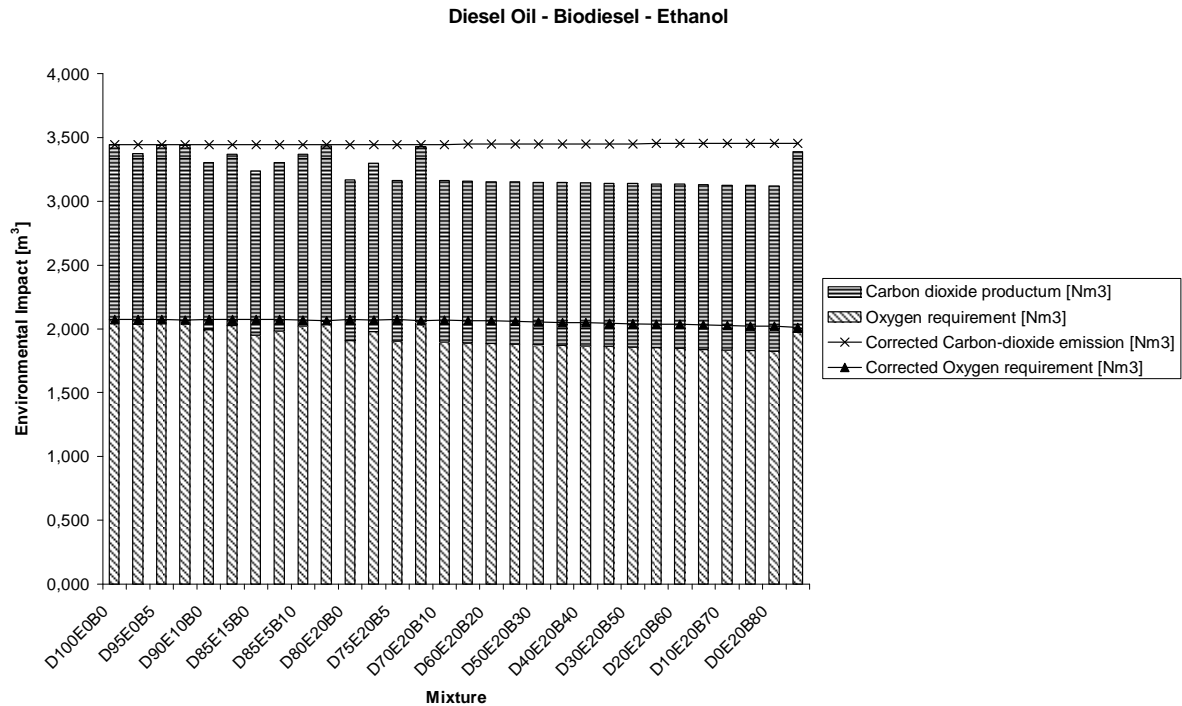


Figure 4: Environmental impact of diesel oil, ethanol and bio diesel mixture

In Figure 4 on the x-axis diesel oil-biodiesel-ethanol blends of different composition are shown. The number after “D” refers to the diesel-oil content, the number after “E” refers to the ethanol content and the number after “B” refers to the biodiesel content. On the vertical axes the environmental impact can be seen without and corrected with the lower heating value. In our theoretical estimation model biodiesel has larger oxygen requirements and higher carbon dioxide production.

Increasing diversification of the energy matrix and reducing reliance on fossil fuels is another advantage of biofuels. That will impact energy security — i.e. the availability of energy at all times, in sufficient quantities and at affordable prices. These conditions must prevail on long term if energy is to contribute to sustainable development. This is a critical subject because of the uneven distribution of fossil fuel resources among countries (6).

The World Energy Assessment (WEA) has pointed out that: “views on the long-term availability of oil and natural gas continue to spark controversy and debate” (UNDP, UNDESA, WEC, 2002). Current trends indicate that the world will continue to depend on fossil fuels for decades to come, with the largest share of the world’s oil resources concentrated in a few areas of the globe. Nuclear fuels are also concentrated in a few countries and nuclear technology raises concerns related to the physical security and environmental aspects of their use.

World market prices for conventional energy sources, in particular oil, are quite volatile. This poses great risks for the world’s economic and political stability, with (sometimes) dramatic effects on energy-importing developing countries. In this context, renewable energies, including biofuels, can help to diversify energy supply and to increase energy security.

CONCLUSION

The high contribution of road transportation to CO₂ emission made the research of relation between road transportation and carbon dioxide emission reasonable.

There is a justifiable demand by the society to moderate the environmental impacts caused by road transportation. We need to look for new renewable sources of energy for transportation, as it is part of the production chain, and cannot be eliminated.

Nowadays the relation between environment and society can be improved by human impact. There are approved technical solutions to substitute fossil fuels in order to reduce environmental impacts. But do they really reduce? According to our estimations the ethanol does not decrease significantly the environmental impact due to its smaller lower heating value. However, the application of biofuels is necessary, because on one hand due to their closed CO₂ cycle additional CO₂ is not emitted to the atmosphere and on the other hand renewable energy sources enable to decrease the international dependency on fossil fuels as they are modifying the energy matrix.

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