Adopting environmental transportation practice in biodise lproduction as key factor for sustainable development: A Bulgarian case study

E. I. Ganev*, B. B. Ivanov, D. G. Dobrudzhaliev, Y. R. Dzhelil, D. Nikolova

Institute of Chemical Engineering, Bulgarian Academy of Sciences, Sofia, Bulgaria

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During the last decades the Bulgarian transport policy is directed mainly towards the construction of modern fast and safe road infrastructure. It corresponds to the geopolitical location of the state in Southeast Europe. Thus, reliable transport corridors will be provided to neighbour states and EU member states. The construction of transport corridors is directly related to the usage of internal combustion engine fuels, used for the vehicles in Bulgaria. The vehicles are based mainly on petrol and diesel engines as the entry of other engines goes at a slow pace. Diesel has become a fuel for trucks and agricultural machinery due to the low fuel consumption and the high efficiency of the diesel engines. On the other hand, the diesel exploitation inevitably reflects on the environment and its pollution because of the volume and the specificity of the waste gases emitted during combustion. Directive 2020 / EU provides the permanent increase of biofuels use. The developed toolbox consists of mathematical model and its optimization for production and use of biofuels, as follows: production and technological criteria, territorial distribution of logistic and production units and environmental pollution with waste gases, consisting mainly CO_2.The results of the toolbox implementation may be used for future effective transport policy for permanent and balanced development of Bulgaria in the next years.

Keywords: Biodiesel, Production technologies, Coordination, GHG emission.

INTRODUCTION

Over the last century, the planet has metaphorically contracted as transport has developed to meet the demands of the population. Global participation in this expansion has been disproportionate [1] as the driving force for transport demand is ultimately the economic growth, which in itself results in an increased need for travel. Although this link is gradually weakening [2], there are few signs of a full breakdown in the unsustainable relationship between increasing incomes and transport emissions [3]. Oil is the dominant fuel source for transportation (Fig. 1a) with road transport accounting for 81% of total energy use by the transport sector (Fig. 1b). This dependence on fossil fuels makes transport a major contributor of greenhouse gases and is one of the few industrial sectors where emissions are still growing [1]. The impact of transport on the global climate is not limited to vehicle emissions as the production and distribution of fuel from oil, a ‘wells to wheels’ approach, produces significant amounts of greenhouse gas in itself [6]. For example, consideration of total CO_2 emissions from an average car showed that 76% were from fuel usage whereas 9% was from manufacturing of the vehicle and a further 15% was from emissions and losses in the fuel supply system [7]. The reliance on transport appears to be causing long-term damage to the climate, and the ever-increasing consumption of fossil fuels means that peak production of petroleum is imminent [4] and world resources will come near exhaustion within 50 years [5]. Rapid decisions now need to be made so that the impacts of transport on the environment can be minimized and fossil fuel resources conserved.

Transport was one of the key sectors highlighted to be tackled by the 1997 Kyoto protocol. The aim was to reduce worldwide greenhouse gas emissions by 5.2% of 1990 levels by 2012. Therefore, since 1997, transport has featured heavily in the political agendas of the 38 developed countries who signed the agreement. Fig. 2a shows that the transport sector accounts for 26% of global CO_2 emissions [8], of which roughly two-thirds originate from the wealthier 10% of countries [9]. Road transport is the biggest producer of greenhouse gases in the transport sector, although the motor car is not solely responsible for all these emissions (Fig. 2b). Buses, taxis and inter-city coaches all play a significant role, but the major contributor is road freight which typically accounts for just under half of the road transport total. Away from road transport, the biggest contributor to climate change is aviation. Aviation is much more environmentally damaging than is indicated solely by CO_2 emission figures. This is due to other greenhouse gases being released directly into the upper atmosphere, where the localized effects can be more damaging than the effects of CO_2alone [10]. Although, the actual energy consumption and CO_2 emissions from

* To whom all correspondence should be sent:
E-mail: evgeniy_ganev@abv.bg

aviation appear relatively low when compared to the motor car (Fig. 2b, Table 1), it is the projected expansion in aviation which is the biggest concern. Air transport shows the highest growth amongst all transport modes and is predicted to be as high as 5% per annum for the next decade [11].

Liquid biofuels (biodiesel and bioethanol) can provide a much needed substitute for fossil fuels used in the transport sector. They can contribute to climate and other environmental goals, energy security, economic development, and offer opportunities for private companies to profit.

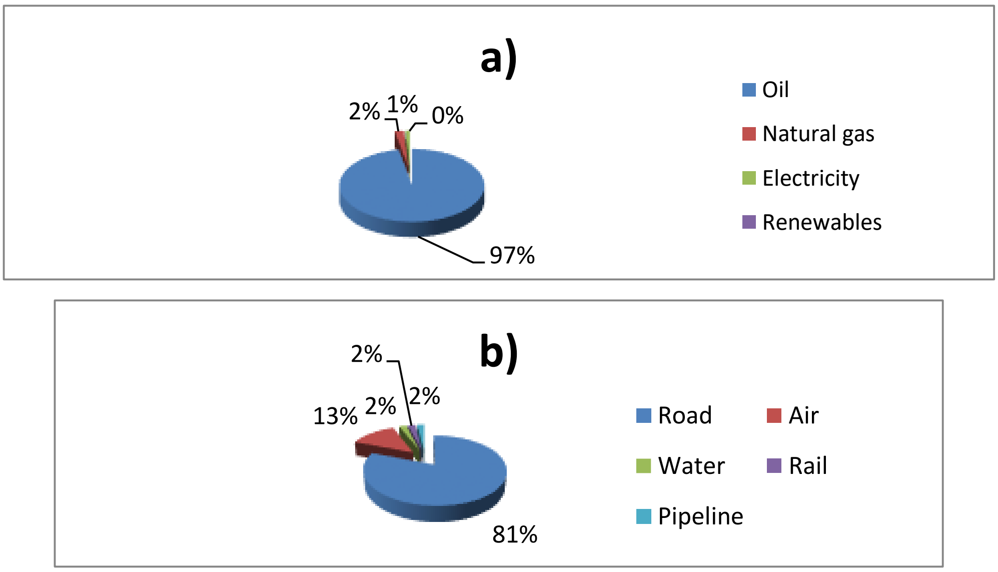

Fig. 1. (a) Fuel use in the transportation sector in OECD(Organisation for Economic Cooperation and Development) countries and(b) shares of transport modes in OECD countries. Source:IEA, 2002.

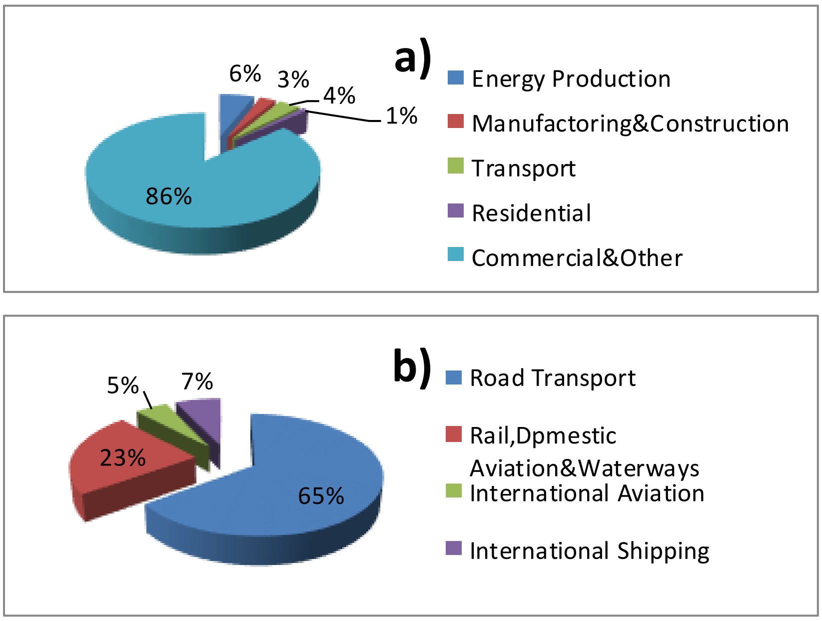

Fig. 2. (a) Carbon dioxide emissions per sector and (b) carbon dioxideemissions per transport sector.Source:IEA, 2000.

If not implemented with care, however, biofuel production can put upward pressure on food prices, increase greenhouse gas (GHG) emissions, exacerbate degradation of land, forests, water sources, and ecosystems, and jeopardize the livelihood security of individuals immediately dependent on the natural resource base.

To this goal we have designed an optimal supply chain (SC) that addresses the entire life cycle of biofuels, from the production of biomass to the combustion of biofuel produced, which should provide an optimal solution for the production of biofuels in order to make their use and production environmentally friendly and not affecting other areas.

METHODOLOGY

Life Cycle Assessment (LCA)has been chosen as the methodology to qualitatively evaluate the environmental loads of the studied fuels. Analysis of a system under LCA encompasses the extraction of raw materials and energy resources, the conversion of these resources into the desired product, the utilization of the product by the consumer, and finally the disposal, reuse or recycle of the product after its service life. The Society of Environmental Toxicology and Chemistry and the International Organization for Standardization **(ISO 14040, 1997; ISO 14041, 1998; ISO 14042, 2000a; ISO 14043,2000b)** developed in the 1990s the LCA methodology. The methodology used falls under the international standards of series ISO14040. The main stages in the aforementioned methodology include:

- Goal definition and scoping;
- Inventory analysis;
- Impact assessment;
- Interpretation.

The goal of this study is to evaluate the environmental performance of biodiesel, based on a life cycle perspective. The assessment includes the extraction of primary raw materials, as well as the combustion of the fuels in the car engine. The system boundaries do not include the production of capital goods, risks and human labor. Major operations within the boundary of the petroleum diesel system include:extract crude oil from the ground, transport crude oil to an oil refinery, refine crude oil to diesel fuel, transport diesel fuel to its point of use and use the fuel in the car engine.

Biodiesel production is achieved*via* different kinds of feedstocks. The nature of feedstock used is dependent on the geographical position and climate of the place. Singh and Singh [12] reported that the major feedstocks employed in producing biodiesel are cotton seed, palm oil, sunflower, soybean, canola, rapeseed, and Jatropha curcas. Additionally, Zhang *et al.* [13] remarked that employing feedstocks such as waste frying oils, nonedible oils, and animal fats, as feedstocks could be useful in producing biodiesel. We look at biomass (sunflower and rapeseed) as feedstock for biodiesel production because they are grown in Bulgaria. The biodiesel is produced by transesterification. Based on Fig. 3, which presents the life cycle of biodiesel and the fossil fuels, it is seen that the first stage in biodiesel chain refers to the cultivation of rapeseed and sunflower grains. After the growth and harvest of plants, the grains are dried and then oil is extracted in two steps, followed by an extraction with an organic solvent (hexane). The solvent is separated and recycled while a small quantity is lost (emission to air). Transesterification of the oil produces methyl esters (biodiesel) and glycerol, which is purified and then used in chemical industry.

Biodiesel can be blended and used in many different concentrations. The most common are B5 (up to 5% biodiesel) and B20 (6% to 20% biodiesel). B100 (pure biodiesel) is typically used as a blendstock to produce lower blends and is rarely used as a transportation fuel.

Low-level biodiesel blends, such as B5, can be used in any compression-ignition engine designed to be operated on petroleum diesel. This can include light-duty and heavy-duty diesel cars and trucks, tractors, boats, and electrical generators. B20 is popular because it represents a good balance of cost, emissions, cold-weather performance, materials compatibility, and ability to act as a solvent. B100 and other high-level biodiesel blends are less common than B20 and lower blends due to a lack of regulatory incentives and pricing. Biodiesel-compatible material for certain parts, such as hoses and gaskets, allow B100 to be used in some engines built since 1994. B100 has a solvent effect, and it can clean a vehicle's fuel system and release deposits accumulated from petroleum diesel use. The release of these deposits may initially clog filters and require frequent filter replacement in the first few tanks of high-level blends.

Comparison of CO_2emissions for biodiesel and petroleum diesel

Figure 4 and Table 1summarize CO_2 flows from the total life cycles of biodiesel and petroleum diesel and the total CO_2 released at the tailpipe for each fuel. The dominant source of CO_2 for both the petroleum diesel and the biodiesel life cycles is the combustion of fuel in the bus. For petroleum diesel, CO_2 emitted from the tailpipe represents 86.54% of the total CO_2 emitted across the entire life cycle of the fuel. Most remaining CO_2 comes from emissions at the oil refinery, which contribute 9.6% of the total CO2 emissions. For biodiesel, 84.43% of the CO_2 emissions occur at the tailpipe. The remaining CO_2 comes almost equally from biomass, biomasses crushing, and biomass oil conversion to biodiesel. Figure 5 shows the effect of biodiesel blend levels on CO_2 emissions

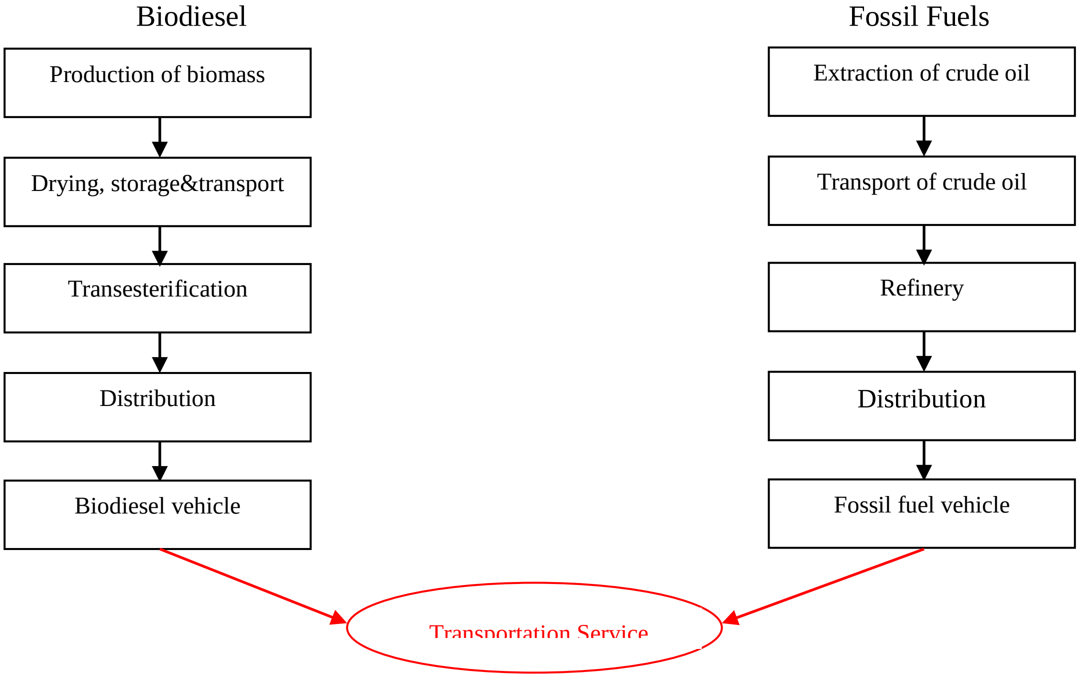

Fig. 3. Life cycle for biodiesel and fossil fuels.

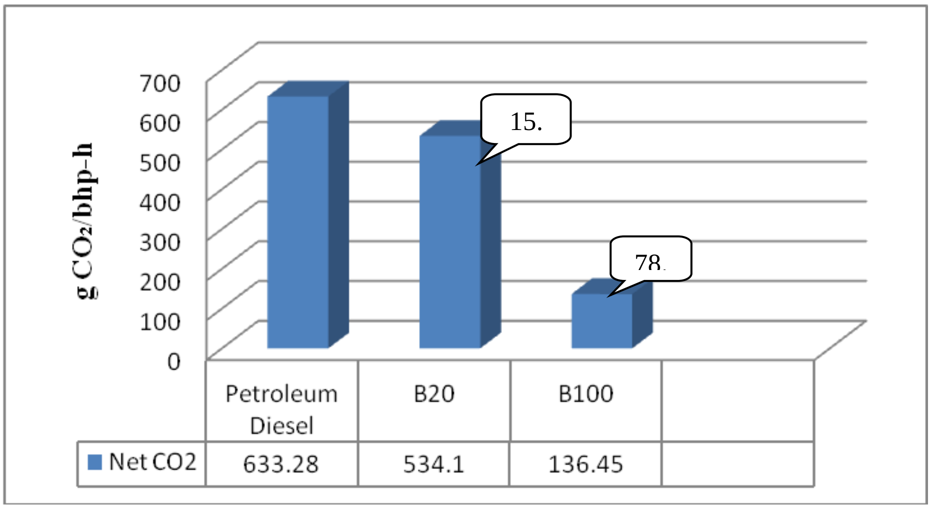

Fig.4. Comparison of net CO_2life cycle emissions forpetroleum diesel and biodiesel blends*.
*Net CO_2calculated by setting biomass CO_2emissions from the tailpipe to zero.

Table 1. Tailpipe contribution to total life cycle CO_2forpetroleum diesel and biodiesel(g CO_2/bhp-h)

Fuel	Total Life Cycle Fossil CO_2	Total Life Cycle Biomass CO_2	Total Life Cycle CO_2	Tailpipe Fossil CO_2	Tailpipe Biomass CO_2	Total Tailpipe CO_2	% of TotalCO_2fromTailpipe
Petroleum Diesel	633.28	0.00	633.28	548.02	0.00	548.02	86.54%
B100	136.45	543.34	679.78	30.62	543.34	573.96	84.43%

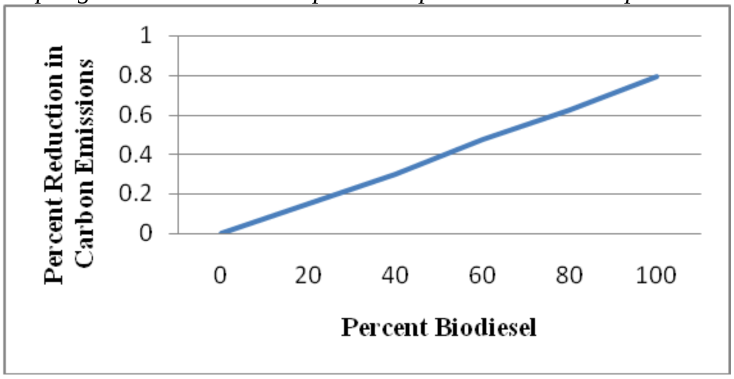

Fig.5. Effect of biodiesel blend level on CO_2emissions.

At the tailpipe, biodiesel (most of which is renewable) emits 4.7% more CO_2 than petroleum diesel. The nonrenewable portion comes from the methanol. Biodiesel generates 573.96 g/bhp-h compared to 548.02g/bhp-h for petroleum diesel. The higher CO_2 levels result from more complete combustion and the concomitant reductions in other carbon-containing tailpipe emissions. As Figure 8 shows, the overall life cycle emissions of CO_2 from B100 are by 78.45% lower than those of petroleum diesel. The reduction is a direct result of carbon recycling in rapeseed and sunflower plants. B20 reduces net CO_2 emissions by 15.66%.

Comparison of life cycle air emissions for biodiesel and petroleum diesel

Figure 6 summarizes the differences in life cycle air emissions for B100 and B20 *versus* petroleumdiesel fuel. Replacing petroleum diesel with biodiesel in an urban bus reduces life cycle air emissions forall but three of the pollutants we tracked. The largest reduction (34.5%) in air emissions that occurs whenB100 or B20 is used as a substitute for petroleum diesel is for CO. The effectiveness of B20 in reducinglife cycle emissions of CO drops proportionately with the blend level. Biodiesel could, therefore,effectively reduce CO emissions in CO non-attainment areas**.**

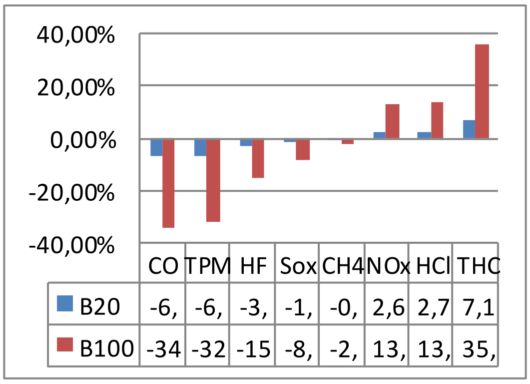

Fig. 6. Life cycle air emissions for B100 and B20compared to petroleum diesel life cycle air emissions.

DISCUSSION

The results of the present study can be used as an input to the strategic decision-making process for future transport energy policy and also to identify key areas of interest for further technology research and development of the Bulgarian transport system. Biofuels Life Cycle Analysis can be considered as a valuable tool, offering flexibility to the system parameterization and to the integrated evaluation of their environmental impacts and their performance in general. Furthermore, it can be a useful tool in the process of strategic and integrated transportation planning, since it takes into account environmental, technical and cost considerations. It is obvious that the use of LCA can result in a shift of the way planners make strategic and operational decisions, through being more effective in identifying improvement opportunities that may not have been previously obvious.

Taken into consideration the fact that the biodiesel is suitable for use in standard compression-ignition (diesel) engines designed to operate on petroleum-based diesel fuel, it is obvious that it can be easily used in existing diesel engines either in its pure form (B100) or in virtually any blend ratio with conventional diesel fuels. Additionally, biodiesel can be strongly promoted through captive and private fleets (bus, taxi, car driver, municipal fleets, etc.).

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ЕФЕКТИВНА И ЕКОЛОГОСЪОБРАЗНА ТРАНСПОРТНА ПОЛИТИКА ПРИ ПРОИЗВОДСТВОТО НА БИОДИЗЕЛ – КЛЮЧОВ ФАКТОР ЗА УСТОЙЧИВО И БАЛАНСИРАНО РАЗВИТИЕ В РАМКИТЕ НА БЪЛГАРИЯ.

Е. И.Ганев*,Б. Б. Иванов, Д. Г. Добруджалиев, Ю. Р.Джелил, Д. Николова

Институт по инженерна химия, Българска академия на науките, София, България

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(Резюме)

През последните десетилетия, транспортната политика на Република България, основно е насочена към изграждане на модерна и сигурна пътна инфраструктура. Това е в съответствие с геополитическото разположение на страната в Европа. Така ще се осигурят надеждни транспортни коридори към съседни нам страни от Европейския съюз. Това е в пряка връзка с използването на горива за двигателите с вътрешно горене, тъй като навлизането на други двигатели върви с бавни темпове. Дизелът, се е наложил като гориво при товарните автомобили и селскостопанската техника, поради високата ефективност, но от друга страна, поради обема на приложение и спецификата на вредните емисии, при изгаряне, експлоатацията на дизела неминуемо се отразава на екологичната обстановка и замърсяването на околната среда. Съгласно Директива 2020 на Европейския съюз е необходимо непрекъснато нарастване на използването на биогорива.

Разработеният инструментариум включва математичен модел и оптимизацията му за производство и използване на биогорива по: производствено-технологични критерии, териториално разпределение на логистични и производствени единици и замърсяването на околната среда с отпадъчни, горивни газове.

Резултатите от приложението на този инструментариум, могат да се използват за изграждане на ефективна транспортна политика за устойчиво и балансирано развитие на Република България през следвашите години.