ECOLOGICAL CONTRIVANCE FOR ANALISIS AND MANAGING THE PRODUCTION OF BIOETHANOL AS A FUEL FOR INTERNAL COMBUSTION ENGINES

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Abstract: *The energy crisis and environmental contamination are two of the main problems of the 21st century. Atmospheric contamination from transport is well-studied case of environmental impact and is associated with significant health consequences. The biofuels use is able to reduce both pollution emitted by transport (CO_2 and other damaging substances into the atmosphere, contributing to global warming) and the reduction of energy dependence on fossil fuels (gasoline, diesel, etc.). European Union requires their use to reach - 10% by 2020. Object of our study is bioethanol, which has great potential to replace gasoline. It was discussed the environmental technique for analyzing and managing the production of bioethanol, aiming to explore all stages of the production chain. It includes a selection of feedstock, site of its cultivation and transport, area for the construction of biorefinery, technology for production and distribution.*

Keywords: *BIOETHANOL, ENVIROMENTAL ACTION, PRODUCTION TECHNOLOGIES, GHG EMISSION, COORDINATION*

1. Introduction

Bioethanol has been used in Germany and France in 1894. Availability of cheap fuel does not allow its production on an industrial scale until it occurs energy crisis and increasing emissions of greenhouse gases that renewed interest in bioethanol and its use **[1].** The European Union adopted Directive in 2008, which obliges all member states to use ethanol in a mixture of gasoline as its use gradually increased to reach 10% to 2020. The use of bioethanol would lead both to reduce emissions leading to greenhouse effect - CO, NOx, CO_2 (the combustion of bioethanol is released so amount of CO_2 as it was absorbed by the plant in its photosynthesis) and to reduce dependence on gasoline.

Bioethanol consumption in the EU transportation sector is given in Fig. 1 **[2]**. In Bulgaria the quantity of bioethanol is equal to 5.3% in 2016.

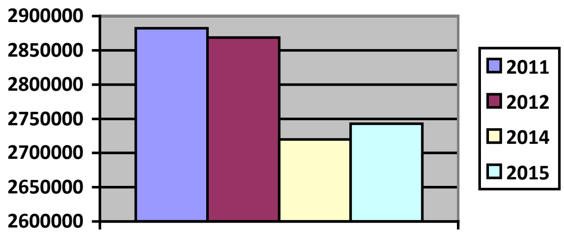

Fig. 1 *Bioethanol consumption in the transportation sector in recent years.*

2. Problem Statement

The problem described in this paper aims to present ecological technique for analyzing and managing the production of bioethanol, building optimal Supply Chain (SC) for bioethanol which minimizes chain costs, the impact on the environment by making appropriate compromises.

3. Bioethanol as a Transport Fuel

The Bioethanol represents ethyl alcohol which can be obtained from cultures containing sucrose (sugar beet, sugar cane, sweet sorghum and sweet potato), starch (wheat, corn, barley, rice and potatoes) and lignocellulose raw material (corn cobs, straw, and wood / forest waste). It has a higher octane rating, a wider range of ignition and improves the efficiency of the engine because it has a high burning rate. Octane number is a standard measure of resistance to detonation motor gasoline and it is conditional unit showing the tendency to the detonation of the test sample, compared with a penchant for detonation of accepted standards. The fuel can withstand higher compression prior to detonate at the higher the octane number.

Bioethanol can be blended in combination with gasoline in different proportions depending on the desired effect. Common proportions: E5, E10, E20, E25, E70, E85, which is a high-level ethanol-gasoline blend containing 85% ethanol and 15% gasoline. E85 and mixtures even with higher concentrations of bioethanol, such as E95, have been considered as alternative fuels. Vehicles fueled called E85 vehicles adaptability to fuel - fuel flexible vehicles (FFVs) and they are available from some major vehicle manufacturers.

- Ethanol-gasoline blends with low ethanol content to 10% may be used in conventional vehicles.
- Ethanol - gasoline blends with higher ethanol - 60-85% and more bioethanol are specifically designed for special-manufactured vehicles characterized by greater flexibility and receptivity to different fuel blends.

The disadvantages of this renewable fuel are that it has a lower energy density than gasoline, lower vapor pressure and corrosive effect. These disadvantages can be avoided such as using volatile additives such as iso-pentane and dimethyl ether

The main properties of gasoline and bioethanol are presented in table. 1 **[3].**

Table 1: *Fuels properties.*

	Density [kg/dm3]	Viscosity [mm2/s]	Flash point [oC]	Caloric value [at 20oC MJ/kg]	Caloric value [MJ/l]	Octane number [RON]	Fuel equivalence [l]
Gasoline	0.76	0.6	<21	42.7	32.45	92	1.00
Bioethanol	0.79	1.5	<21	26.8	21.17	>100	0.65

4. Feedstocks for Bioethanol Production

In compliance with the EU Directive it is necessary to provide as available arable land earmarked for the cultivation of biomass and new areas to increase the amount of received and used bioethanol. It should be borne in mind also the geographical location of biorefinery, the local soil conditions and biomass yield per hectare. Different types of biomass with their production capacity are given in the Table. 2 **[4]:**

Table 2: *Feedstock for bioethanol production.*

Biomass	Production potential of bioethanol (l/t)
Sugar cane	70
Sugar beet	110
Potatoes	110
Corn	360
Rice	430
Barley	250
Wheat	340
Sweet Sorghum	60

Feedstocks containing sugar can easily be converted into bio-ethanol by fermentation, and those that contain starch are made up of many glucose molecule chains which are cleaved to produce the sugars and fermenting. Bioethanol production from lignocellulosic biomass is more difficult technology, because they consist primarily of lignin, cellulose, proteins, fats, waxes, and a small amount of: starch, sugars, proteins and lignin.

Global Bioethanol production in recent years is illustrates in fig. 2. The figure shows that its production gradually increases **[5].**

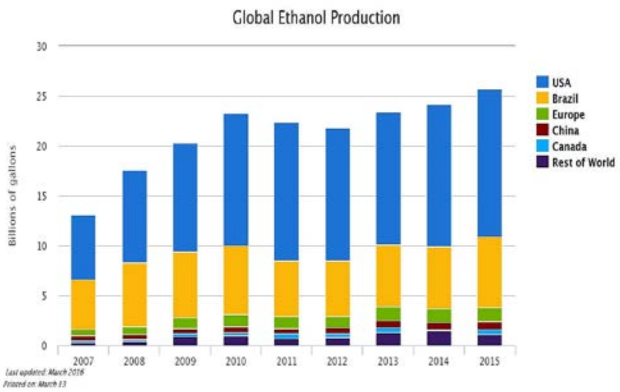

Fig.2 *Global Bioethanol Production.*

5. Bioethanol Production

Bioethanol must be produced in compliance with the following requirements to be clean:

- In the cultivation of biomass to avoid land rich in carbon, as the plant will take it and release it during the combustion.

- By-products must be recovered efficiently and reused.

- To reduce those emissions throughout the entire life cycle of production and use of this fuel. Emissions take place as from cultivation, collection, and transportation and in their conversion to bioethanol and logistics of finished fuel.

- To build a SC for bioethanol by which to choose the optimal technology for its receipt, and the selection of feedstock as well as the locations where they are installed biorefineries with their production capacities to make the necessary compromises.

An environmental SC should consider all stages of production of the fuel: the choice of raw material to its incineration and disposal of waste products. It also considers the emissions released in each stage of production and lead to their reduction by choosing the optimal of all possible feedstocks and technologies.

SC analyzes the different stages of the production of bioethanol. It provides the ability to manage manufacturing processes, including the selection of the most favorable environmental and economic criteria. Development of appropriate SC represents a powerful tool for ensuring sustainable development of modern energy. This includes the joint implementation of the criteria of economy and ecology. It is also possible to include social decisions.

Ecological technique for analysis and management of production of bioethanol (as fuel for internal combustion engines), including design of appropriate SC represents the development of a complex hierarchical structure of decision-making. The main stages of the production of bioethanol are:

Choice of biomass - it is selected depending on the geographical location and climatic conditions. At this stage are chosen and tips and techniques for harvesting, as well as space for its storage and transport (selected type of transport and routing).

Choice of locations for building biorefineries - depending on areas of growing biomass.

Choice of technology for conversion, here we have to choose the following stages:

- *Pre-treatment* - it depends on the type of the biomass. The sugar feedstocks in this step are cleaned, crushed and is carried out extracting sugars and juices processing. First the starch materials are pulverized and subjected to hydrolysis by a suitable enzyme for the cleavage of the glucose molecules:

$$(C_6H_{12}O_6)n+nH_2O \rightarrow nC_6H_{12}O_6$$

D-glucose

The step pre-treatment of the lignocellulosic biomass required to separate holocellulose of lignin and further its conversion to glucose. The aim of pretreatment is to break down the structure of lignin and cellulose, which will improve access of enzymes to the pulp during the hydrolysis stage.

Suitable treatments of lignocellulose are the following: a physical pre-treatment (steam physical treatment, milling, irradiation, temperature and pressure), which would increase the available surface area, pore size and would result in a reduction of crystallinity and degree of polymerization of cellulose, physical-chemical (including automatic hydrolysis), chemical (ozonolysis, alkaline and acid) and organic. After this treatment is carried out the hydrolysis, which can be chemical or enzymatic;

- *Diluting the sugars in water and then adding yeast;*

-*Fermentation* - at this stage must be selected type yeast / enzymes;

- *Distillation* – for remove water;

- *Dehydration* - drying of bioethanol as it can be used as fuel for internal combustion engines, here choose the appropriate methods for dehydration;

Choice of transport and route for transporting of a ready fuel to places for blending with gasoline

Selection of areas for construction of installations for mixing of bioethanol with gasoline

Logistics - choice of transport route for transportation of bioethanol-gasoline blend to the gas stations.

The stages of the production of bioethanol vary depending on the type of feedstock.

Table 3: *Ethanol production steps by feedstock and conversion technique*

Feedstock	Feedstock conversion to sugar	Process heat	Sugar conversion to alcohol	Co-product
Cane	Sugars extracted through bagasse crushing, soaking, chemical treatment	Primarily from crushed cane (bagasse)	Fermentation and distillation of alcohol	Heat, electricity, molasses
Sugar beet	Sugar extraction	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed, fertilizer
Wheat	Starch separation, milling, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g. distillers dried grains)
Corn	Starch separation, milling, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g.g.distillers dried grains), sweetener
Potatoes	Washing, mashing, cooking, starch separation, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed, industrial use
Trees	Cellulose conversion to sugar via saccharification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc
Forestry waste	Cellulose conversion to sugar via saccharification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.

We must keep the following criteria for Environmental and economical production of bioethanol:

<u>*Economic criteria*</u> include: the costs of handling, transportation and storage of biomass, transport costs of biomass from store to store to biorefinery, costs for its transformation, transportation costs of biofuels by blending facility and the transport cost to transporting of finished product to warehouses for storage.

(1) $IK=IR+IBH+IBT+IBI+IBD+IP+IPI+IPT\text{-}IPC$

where,

IR- annual capital costs;
IBH- total cost of harvest, (€/kg);
IBT- total transport cost of biomass, (€/kg);
IBI- storage costs of the biomass, (€/kg);
IBD- handling costs of the biomass, (€/kg);
IP- production costs, (€/kg);
IPI- cost of fuel storage, (€/l);
IPT- general transportation costs of bioethanol, (€/l);
IPC- Government incentives for biofuel production, (€/l);

<u>*Environmental criteria-*</u> its aims to minimize the total annual amount of greenhouse gases (GHG) emitted during the lifecycle of SC.

The three main greenhouse gases emitted by a SC are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Total GHG emissions are measured from the point of view of CO_2 - equivalent emissions (CO_2-eq). Greenhouse gases are 1g CH_4 = 25g CO_2-eq. and 1g N_2O = 298g CO_2-eq according to the latest assessment report of the Intergovernmental Panel on Climate Change **[6]**.

Emissions separated from bioethanol production are illustrated in Fig. 3.

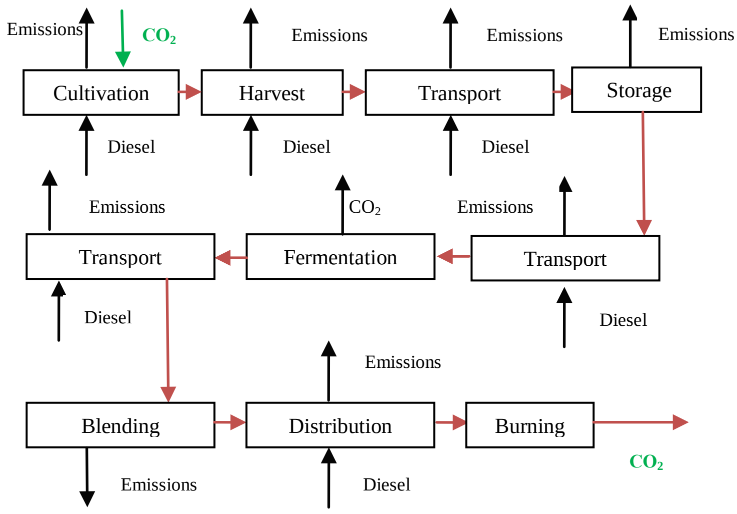

Fig.3 Separated emissions during the lifecycle of production.

The equation for the calculation of the ecological criteria and the minimizing of CO_2 emissions is:

(2) $EK=Kbh+Kbd+Kbi+Kbt+Kp+Kpt+Kpm+KBcar+KGcar$

where,

Kbh – The emission of cultivating and obtaining biomass, (*kg CO_2-eq/ kg биомаса*);
Kbd – The emission of drying unit amount of biomass, (*kg CO_2-eq/ kg биомаса*);
Kbi – The emission of storing unit amount of biomass, (*kg CO_2-eq/ kg биомаса*);
Kbt – The emission of transporting unit amount biomass, (*kg CO_2-eq/ kg биомаса*);
Kp – The emission of producing unit amount biofuel from biomass, (*kg CO_2-eq/ kg биомаса*);
Kpt – The emission of transporting unit amount biofuel, (*kg CO_2-eq/ l*);
Kpm – The emission of blending and distributing unit amount of biofuel, (*kg CO_2-eq/ gallon*);
KBcar – The emission emitted using biofuels in transport, (*kg CO_2-eq/ l.*);
KGcar – The emission emitted using conventional fuels in transport, (*kg CO_2-eq/ l.*).

6. Conclusion

Biofuel production is expected to quickly develop during the next decades, Biofuel production is expected to develop rapidly in the coming decades because of growing environmental pollution, the inefficient use of energy and energy crisis. Energy future of the world is inextricably linked with the development of techniques for the controlled production of biofuels.

This paper presents an approach for Bioethanol Supply Chain on economic and environmental criteria, taking into account the main characteristics of biofuels such as seasonality for supply of raw materials, geographic diversity and availability of biomass, other conversion technologies, recycling of by-products, distribution demand, and regional economic situation. Presented model allows minimizing the economic costs and the reduction of harmful emissions released in the chain by making the necessary compromises. The design of optimal SC for biofuel can solve a wide range of issues related to biofuels, because this area changes very fast (not only economic but also includes strategic decisions relating to domestic consumption or export the produced biofuel producing region biomass, etc.).

The analysis and production management presented the used area is flexibility and the ability to solve many problems simultaneously by the methods of mathematical modeling.

7. Acknowledgements

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8. Literature

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