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USE OF BIOETHANOL IN TERMS OF CARBON DIOXIDE EMISSION

Environmental protection as well as energy management are the most troublesome problems for industry. Renewable sources of energy can allow us to solve both problems. The paper deals with a total energy balance and net CO_2 balance in the cycle of bioethanol production. The analysis of those balances shows the advantages and disadvantages of using bioethanol as a component of liquid fuels.

1. GLOBAL PROBLEMS OF CO_2 EMISSIONS

The greenhouse effect is due to an excessive heat accumulated by the Earth. About thirty gases are believed to be responsible for this effect. These gases build a layer which creates a barrier for IR radiation leaving the Earth atmosphere. The main components of this layer are as follows: carbon dioxide, methane, ozone, nitrogen oxides and freons. The absorptivity of CO_2 particles with respect to of IR radiation is the lowest, but because of its highest concentration compared to other greenhouse gases, CO_2 has the biggest (50%) influence on this effect. At the beginning of the XX century the concentration of carbon dioxide in the Earth atmosphere was constant and equal to 0.03%. Along with the industry development, this concentration has begun to increase considerably. The most rapid increase took place in the last century between the ’50’s and the ’80’s. This was the result of a dynamic development of mining industry – combining oil, natural gas and coal exploitation – releasing a large amount of coal from deposits to the atmosphere. In the eighties of last the century, the emission declined slightly due to a better proecological policy, more effective technological processes, better sources of raw materials and more efficient waste management. The increase in CO_2 concentration in the last fifty years following the recordings of CO_2

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concentrations from the Mauna Loa Observatory in Hawaii [1] is independent of local influence and equals 64 ppm, which means its increase of ca. 20%.

The main problems steaming from greenhouse effect can be itemized as follows:

- displacement of climatic zones towards the poles,
- progressive decline of boreal forest areas,
- elimination of tundra and an increase in desert and steppe areas,
- increase in ocean and sea level caused by glaciers melting in the Antarctica and the Arctic.

Global warming concerns the whole of Earth population. The majority of countries decided to combine their efforts by signing an international alignment in order to reduce the greenhouse gas emissions and to monitor the changes of the climate. The UNO conference took place in 1997 in Kyoto, where the representatives of 159 countries took steps to reduce of the greenhouse effect. To that end the signatory countries drew up the protocol, in which they decided to reduce the greenhouse gas emission in the years 2000–2012 to about 6% (on average).

The Sixth International Conference which took place in November of 2000 was based on the Kyoto Protocol and devoted to minimizing the greenhouse effect. The main subject of discussions were the difficulties in adapting to the Kyoto Protocol. As it turned out some countries (USA, Canada) not only did not reduce their emissions, but they increased them. The Kyoto Protocol mentiones six gases: carbon dioxide, methane, nitrogen dioxide and the three gases from the freon group. Some of them are produced by vehicle engines.

The countries that signed the Protocol decided to put into practice the following ideas:

- the improvement of energy management in all branches of industry,
- the promotion and implementation of technologies that use renewable sources of energy,
- accomplishing the reforms that allow reduction of greenhouse gas emissions and multiple possibilities of its absorption.

2. CO_2 – MASS AND ENERGY BALANCE IN THE CYCLE OF BIOETHANOL PRODUCTION

One of the factors that prevents the greenhouse effect is the reduction of CO_2 emission through the replacement of a part of classical fuels with ethyl alcohol produced from plants. The fuel made by this method contains from 2 to 10% of ethanol and its combustion parameters are very similar to these of a normal fuel. Because ethanol is produced from the biomass, there is no doubt that its CO_2 balance will be better.

The authors wanted to answer the following question: what is the energy and what are environmental reasons that speak in favour of using bioethanol as a liquid fuel? It was necessary to calculate the whole detail energy effect and CO_2 emission and absorption. The Polish conditions and biomass (corn and rye kernels) production as well as bioethanol plant production and its dehydration were considered. The bioethanol production at a bioethanol plant owned by the Oil Refinery "Glimar" in Gorlice (Poland) is described.

To calculate the energy and CO_2 input and output in the cycle of bioethanol production the simulation program was written, which allowed us to deal with different input data. It is also possible to change many parameters such as mass and energy balance, farm transport and energy conversion at power plants, depending on specific, regional and technical conditions of bioethanol production.

The stages of bioethanol contact with the surrounding environment are as follows (figure 1):

STAGE 1 – plant cultivation,
STAGE 2 – kernel transport,
STAGE 3 – bioethanol production,
STAGE 4 – bioethanol transport,
STAGE 5 – bioethanol combustion.

The algorithms for calculating the above stages consisted in monitoring all energy and mass flows, following the entire cycle of bioethanol production. In order to understanding better the calculation method [2], the analysis of stage 1 (plant cultivation) is shown below.

Its first step was to estimate the amount of fertilizers (nitrogen, potassium, phosphate) and other chemicals (herbicide, pesticide) needed to grow the corn or rye that will be the substrate for ethanol production. The next step was to estimate the energy necessary for producing the mass unit of each fertilizer and chemical, adding the energy used to obtain and transport them. In this step, it was important to find out what kind of energy carrier (coal, gas, LPG, gasoline, diesel, other) was used to produce and transport each fertilizer or chemical. These data were then used to calculate the whole energy necessary to produce a mass unit of each fertilizer and chemical based on the energy carrier employed (all thermal inputs and outputs in this study are based on a gross high heat value), and simultaneously CO_2 emission from the fuel used is estimated. The data for electricity are based on coal generation. If an the average harvest yield is known, the energy necessary for growing the mass unit of corn or rye can be calculated. Adding the energy necessary for the corn harvest to this result, an extra environment loading is also known. Before totalling all energy carriers used to grow the mass unit of corn or rye, each of them was multiplied by the input efficiency factor [2] that prescribed all the energy costs (mining, distillation, processing, transport) to have each energy carrier in the form used. Now the total energy of energy carriers could be added and the whole energy cost of the cultivation stage was calculated. Based on the kind and quantity of primary energy carriers used to grow the corn or rye, the total CO_2 emission was estimated with reference to mass unit of both cereals.

Of course, at this stage, in CO_2 balance, the CO_2 absorption was most important. It was also estimated in reference to one mass unit of the cereals. Analyzing the Stage 1, two scenarios related to straw were considered. The straw could be ploughed (ecological scenario), or combusted (energetic scenario). Each scenario influenced the energy and CO_2 balance.

3. SUMMARY AND CONCLUSIONS

Figure 2 shows main energetic costs in the third stage (bioethanol plant) of the entire bioethanol cycle production. In this case, the cost is approximately 30 000 kJ/kg. The second stage in the energetic input is the cereal cultivation with the necessary work, fertilizers, chemicals, seeds, harvesting and kernel drying. In the 2nd and 4th stages,

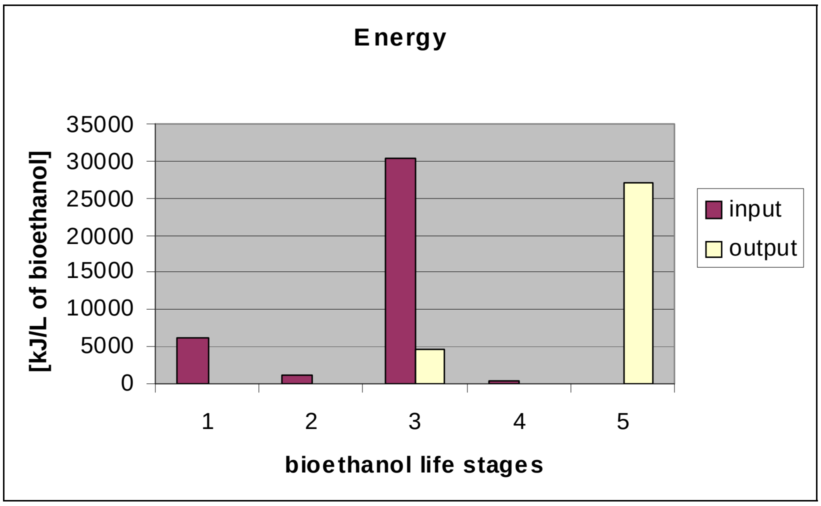

Fig. 2. The energy input and output in the cycle of bioethanol production without energetic use of straw

i.e. the transport and storage of kernels and bioethanol, energy costs are very low. In the energy balance shown in figure 3, the energy included in straw is taken into account. It is interesting that balanced energy gain produced by straw that accompanies the grain production is much higher than energy gain obtained from ethanol production. Figures 4 and 5 show the CO_2 emission related to the 5th stage. If straw is ploughed into soil (in the 1st stage), the superiority of absorption compared with CO_2 emission is distinct. In the case of energetic use of straw (figure 5), the CO_2 emission is visibly higher. The part of CO_2 emission in the 3rd stage, i.e. bioethanol at bioethanol plant production, is absorbed, because some of the carbon dioxide produced in the

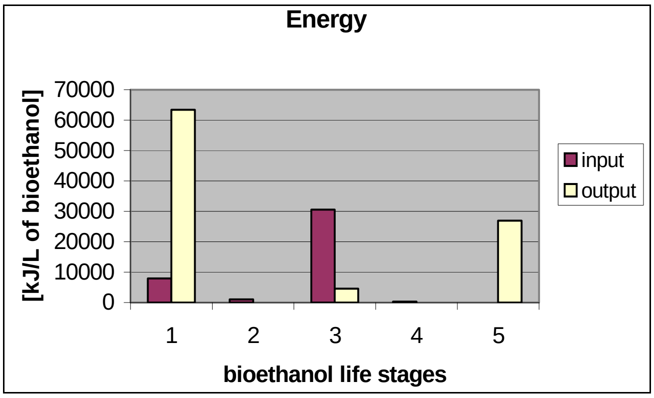

Fig. 3. The energy input and output in the cycle of bioethanol production with energetic use of straw

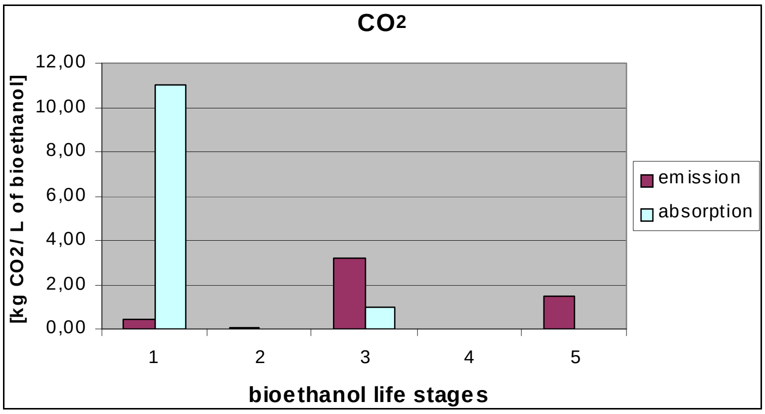

Fig. 4. CO_2 emission and absorption in the cycle of bioethanol production without energetic use of straw

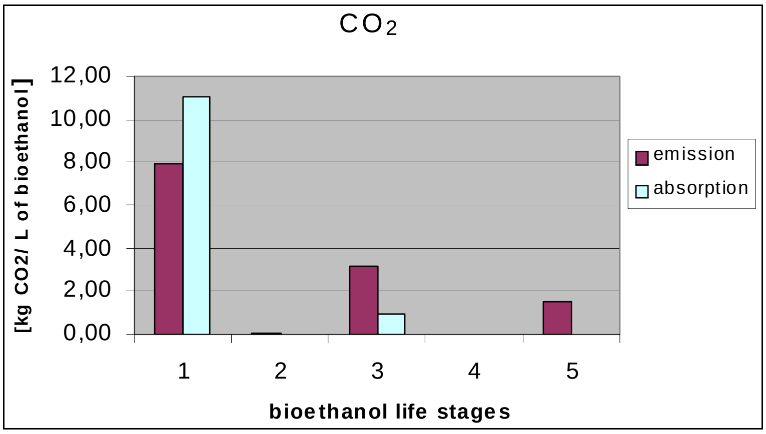

Fig. 5. CO_2 emission and absorption in the cycle of bioethanol production with energetic use of straw

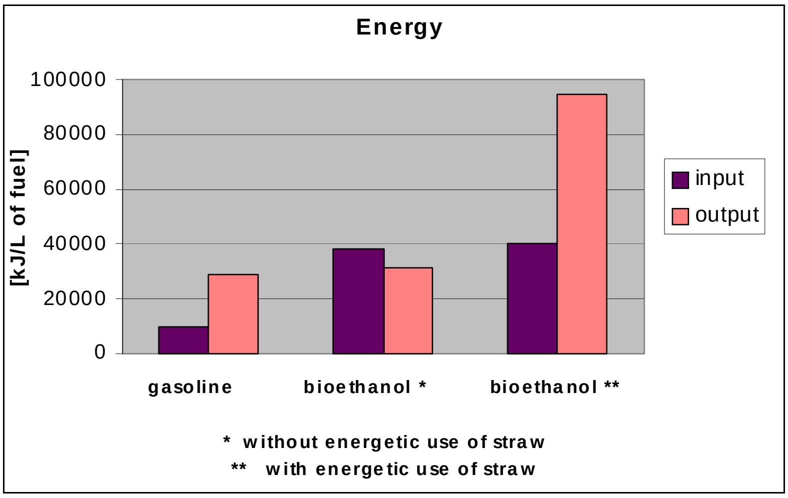

Fig. 6. Comparison of the energy inputs and outputs for gasoline, bioethanol, and bioethanol with energetic use of straw

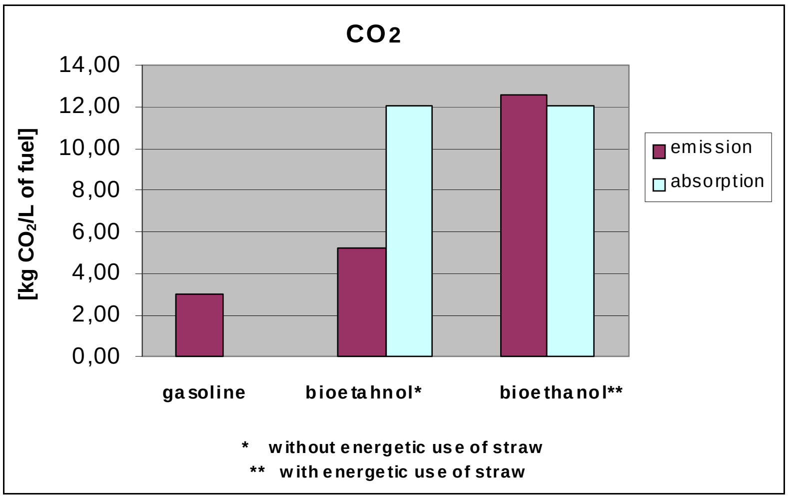

Fig. 7. Comparison of the CO_2 emission and absorption for gasoline, bioethanol, and bioethanol with energetic use of straw

fermentation process is recovered for its technical use. Figures 6 and 7 show the energy and CO_2 balance compared with the balance of gasoline and bioethanol combustion in two stages. Without energetic use of straw, the energy obtained as a result of bioethanol combustion is lower than the energy necessary for its production. This is probably due to the fact that bioethanol plant equipment and technology are energy-consuming. The results show that more profitable, in terms of energy consumption, is the use of bioethanol with energetic combustion of straw. The balance of CO_2 emission is also better, because in the case of gasoline there is no CO_2 absorption at all. There has been some question about the proportion of the prices of fuels and emitted CO_2 in terms of environment pollution. It will have a decisive influence on the final effect, but taking account of environmental protection the use of bioethanol will be highly profitable.

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WYKORZYSTANIE ENERGETYCZNE BIOETANOLU W ASPEKCIE EMISJI DWUTLENKU WĘGLA

Ochrona środowiska naturalnego i gospodarka energetyczna są niewątpliwie najważniejszymi problemami, z jakimi musi się zmierzyć dzisiejszy przemysł. Odnawialne źródła energii mogą być rozwiązaniem obu tych problemów. W artykule przedstawiono całkowity bilans energetyczny oraz bilans emisji i absorpcji CO_2 w cyklu produkcji bioetanolu. Wyniki tego bilansu pokazują wszystkie zalety i wady bioetanolu jako składnika paliw płynnych.