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ENERGY BALANCE OF BIOETHANOL: A SYNTHESIS

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Introduction

Extensive research has aimed at evaluating the so-called **energy ratio** and **CO_2 balance** of bioethanol through the approach of life-cycle assessment (LCA), to assess its capability as a fuel to substitute non renewable energy resources and avoid GHG emissions.

The **objective** of the present work is:

- to present a synthesis of various studies on bioethanol energy balance
- to introduce an environmental assessment approach considering the entire life cycle of the fuels.

The energy balance of bioethanol

Results in the literature vary quite significantly and sometimes even lead to contradictory conclusions. Amongst the most influent parameters, are the nature and type of the feedstock, the types of fertilisers, the crop and bio-ethanol yields, the fate of by-products, the **allocation method**, and more generally, the quality of LCI data (reliability, coherence).

The **energy ratio**, however, is limited to the production of the biofuel. The real capability of bioethanol to substitute non renewable energy and avoid GHG emissions lies in the comparison with fossil fuels and must take into account the respective **performances of the fuels**, thereby considering the **entire life cycle** of the fuels.

An improved approach

The performance of bioethanol as a fuel can be measured by the volume of gasoline it replaces (with the same distance travelled), which depends on the incorporation rate (**ir** in % vol. or $l_{bioethanol}/l_{blend}$) of ethanol in gasoline:

$$e/r\ [l_{gasoline}/l_{bioethanol}] = \frac{c_{gasoline}\ [l/100\ km] - (1-ir)\cdot c_{blend}\ [l/100\ km]}{ir\cdot c_{blend}\ [l/100\ km]}$$

When ethanol is blended with gasoline at **ir=10%**, the equivalence ratio (**e/r**) is 1. With heating value of 21.3 MJ/l and an energy ratio of 1.08, the consumption of non renewable energy in the production of bioethanol is 19.7 MJ/l. The value for gasoline, according to the ecoinvent LCI database is 43.4 MJ/l (corresponding to an energy ratio of 0.74). The capability of fuel ethanol to substitute non renewable energy is calculated as:

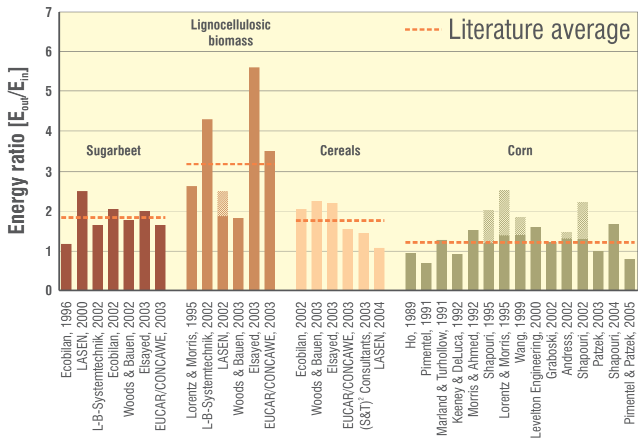
$$\Delta E = 19.7\ [MJ/l_{bioethanol}] - 43.4\ [MJ/l_{gasoline}]\cdot e/r = -23.6\ [MJ/l_{bioethanol}]$$

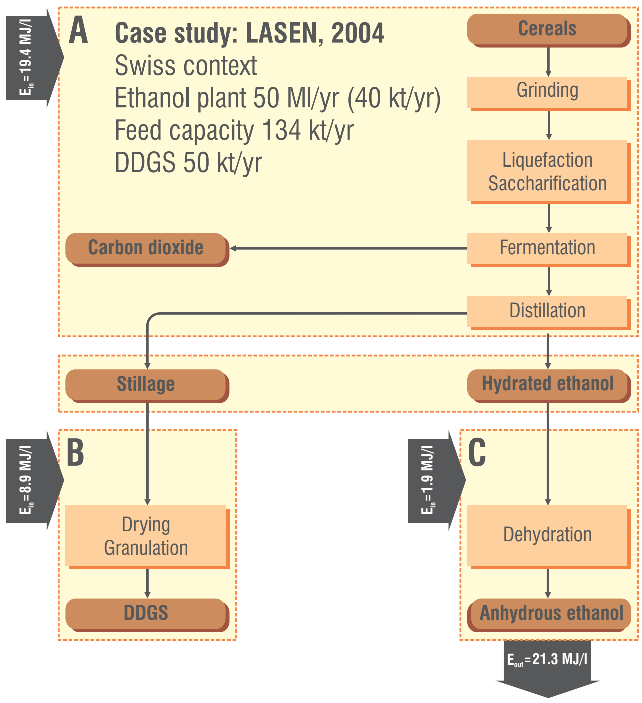
Each ton of bioethanol used as E10 avoids the use of **0.7 t of crude oil eq**. Similarly, the GHG emissions avoided amount to **1.8 t $CO_{2\,eq.}/t_{bioethanol}$**.

Conclusions

The energy ratio does not measure the capability of a biofuel to substitute non renewable energy. The entire life cycle must be taken into account.

Even the most pessimistic energy ratios found in the literature (including Pimentel's results) lead to a net reduction of the non renewable energy use and GHG emissions, when bioethanol is blended with gasoline at low rates (i.e. 5-10%).





Allocation method	%A	%B	%C	Energy ratio
Without allocation	100	100	100	0.70
Economic value	95	95	95	1.08 (0.83)
Energy content	61	61	61	1.54
System extension	81	81	81	1.21
Mass	12	12	12	5.01 (1.56)

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