Life cycle analysis of biofuels for transportation used in fuel cells and conventional technologies under European conditions

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Introduction

Green fuels are said to be clean and may contribute significantly to a sustainable transport system as they save a reasonable amount of fossil resources and have almost no impact on the greenhouse effect due to their CO_2 neutrality. Concerning electric vehicles with fuel cells powered by biofuels there are even more expectations because of their (almost) zero emission of toxic pollutants. But having a close look on the whole life cycles, biofuels can also provoke negative impacts on the environment, caused for example by the agricultural production of the raw materials.

This paper gives an comprehensive overview of the environmental implications due to the use of several biofuels for transportation used in fuel cells as well as in conventional technologies compared to several fossil fuels used under the same conditions. They were deducted within the scope of two extensive investigations recently completed and financed by the European Commission and the German Parliament, respectively (/1/, /2/).

Frame and Definitions

?? Biofuels investigated: bio-ethanol, bio-methanol, biodiesel from rape seed oil, regenerative-hydrogen, bio-DME.

?? Systems under study: Table 1 shows a selection of comparisons of analysed fuels and conversion technologies

?? Method: Life Cycle Assessment (LCA) according to ISO 14040 – 43

?? Time and geographic reference: Europe 2010.

?? Impact categories: Seven impact categories were calculated on the basis of the respective balancing parameters: carcinogenity (as a special form of human toxicity), acidification, eutrophication, photo smog, ozone depletion, greenhouse effect, consumption of energetic resources.

Results

Table 1 shows the results of the assessments of all impact categories under investigation (relative differences related to the reference Otto-ICE). Some main results are:

?? Carcinogenity: The results are dominated by the conversion concepts and types of fuels. FC concepts with hydrogen and natural gas-ICE show much better results than Otto- and Diesel-ICE concepts. The origin of DME, methanol and ethanol – biogenic or fossil – do not play an important role.

?? Acidification, eutrophication, photo smog: These categories are dominated by the origin of the fuels. For biofuels from agriculture (ethanol, RME) disadvantages arise from NO_X and NH_3 emissions of the fertiliser production and especially caused by the application of fertilisers. For biofuels from residues (DME, methanol) disadvantages result from the emissions of the biomass gasification plant.

?? Ozone depletion: There are big uncertainties. For biofuels from agriculture disadvantages from soil emissions can be observed.

?? Greenhouse effect: The calculations show big advantages of all biofuels, affected by N_2O emissions in a small degree only.

?? Exhaustible resources: The results correspond to those of the category greenhouse effect. For small relative impact differences the sign can be different for greenhouse effect and resource consumption.

Summary and conclusion

?? As a rule bigger benefits (or smaller disadvantages) can be observed with fuel cells compared to Otto-ICE for all fuels under investigation. This is due to zero emissions during usage and high efficiencies of these conversion systems.

?? Comparing all impact categories there is no clear result pro or con biofuels: advantages concerning greenhouse effect and resource consumption and disadvantages concerning the regional impacts acidification, eutrophication, and photo smog.

?? The final assessment therefore depends unavoidable on subjective value choices. But the criteria "specific contribution", "ecological endangering" and "distance to target", which will be discussed in detail in the full paper and the presentation, allow at least very plausible choices. Combining the results of the Table and the three criteria a reasonable overall assessment can be carried out.

Table 1: Results for some options under study (relative differences related to the reference Otto-ICE)

Impacts / Systems & Fuels	Carcino-genity	Acidifi-cation	Eutrophi-cation	Photo smog	Ozone depletion	Greenhouse effect	Consumpt. Energetic resources
Otto-ICE	0%	0%	0%	0%	0%	0%	0%
Diesel-ICE	64%	33%	76%	-7%	-21%	-17%	-18%
LNG-ICE	-94%	-25%	-5%	-48%	-2%	-15%	3%
LH2(z_fos)-ICE	-97%	59%	76%	-11%	26%	81%	123%
LH2(z_reg)-ICE	-97%	-49%	-22%	-90%	-5%	-96%	-98%
DME-ICE	-93%	-6%	17%	-10%	-22%	-1%	29%
BioMeOH-ICE	1%	189%	323%	252%	37%	-84%	-85%
BioEtOH-ICE	-1%	249%	322%	79%	689%	-76%	-96%
RME-ICE	64%	255%	430%	-2%	1405%	-41%	-74%
BioDME-ICE	-92%	168%	297%	238%	15%	-86%	-86%
LH2(z_fos)-FC	-98%	-25%	-32%	-53%	-79%	16%	45%
LH2(z_reg)-FC	-98%	-95%	-95%	-98%	-99%	-99%	-99%
MeOH-FC	-98%	-55%	-63%	-59%	-96%	-6%	22%
DME-FC	-98%	-56%	-64%	-57%	-97%	-5%	25%
BioMeOH-FC	-98%	107%	199%	174%	-62%	-88%	-87%
BioDME-FC	-98%	113%	209%	185%	-61%	-88%	-87%
BioEtOH-FC	-100%	233%	283%	43%	669%	-76%	-95%

Abbreviation	Description
Otto-ICE	Otto-PC (**ICE**: internal combustion engine in passenger car)
Diesel-ICE	Diesel-passenger car
LNG-ICE	Otto-passenger car, liquid natural gas
LH_2(z_fos)-ICE	Otto-passenger car, liquid hydrogen from natural gas
LH_2(z_reg)-ICE	Otto-passenger car, liquid hydrogen from regenerative electricity
DME-ICE	Diesel-PC in DME-operation (DME: dimethyl ether)
BioMeOH-ICE	Otto-passenger car in biomethanol-operation (biomethanol from residual wood)
BioEtOH-ICE	Otto-passenger car in bioethanol-operation (bioethanol from sugar beet)
RME-ICE	Diesel-passenger car in RME-operation (RME: rape seed oil methyl ester)
BioDME-ICE	Diesel-passenger car BioDME-operation, DME from residual wood
LH_2(z_fos)-FC	Liquid hydrogen from natural gas, (**FC**: fuel cell in passenger car)
LH_2(z_reg)-FC	Liquid hydrogen from regenerative electricity
MeOH-FC	Methanol from natural gas
DME-FC	Dimethyl-ether from natural gas
BioMeOH-FC	Biomethanol from residual wood
BioDME-FC	BioDME from residual wood
BioEtOH-FC	Bioethanol from sugar beet IFEU 2001

Literature

[1] Bioenergy for Europe: Which ones fit best? – A comparative analysis for the Community. Funded in part by the European Commission (FAIR CT 98 3832), Heidelberg/Bruxelles, 2001

[2] Ecological comparison of vehicles with different conversion technologies and fuels. Funded by the Office for Technology Assessment at the German Parliament), Heidelberg 1999/2000