EVS24
Stavanger, Norway, May 13-16, 2009

Sustainability of Transport Fuels

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Abstract

Sustainability criteria for biofuels are becoming legal requirements in the European Union in combination with a binding target to achieve 10% renewable energy in transport by 2020. A systematic structure of sustainability criteria developed by the authors facilitates the comparison of legal and voluntary criteria catalogues. Results presented here highlight the challenges in meeting the major sustainability criteria with biofuels on a large scale. Focus is put on greenhouse gas (GHG) emissions, land-use and water intensity of different fuel and power train options. Electricity and hydrogen based on renewable energy are equal options to achieve the 10% target. Both perform superior to most biofuel options on a well-to-wheel basis with key sustainability criteria and their compliance is more robust. Electricity and hydrogen based on renewable energy can achieve full sustainability goals on scales beyond current energy consumption levels.

Keywords: alternative fuel, emissions, environment, LCA (Life Cycle Assessment), sustainability

1 Introduction

Public debates on the environmental footprint of biofuels have led to the inclusion of a broad range of sustainability criteria that flank the introduction of mandatory renewable energy targets in European.

2 Sustainability Schemes

Public concern is focussed on the sustainability of energetic biomass production for mobile and stationary purposes. There is no general solution to this complex for biofuels like ethanol, biodiesel or plant oils. Hence, several voluntary initiatives have formed to develop sustainability criteria, such as the Roundtable for Sustainable Palm Oil (RSPO), the Forest Stewardship Council (FSC) and the GlobalGAP (Global Partnership for Good Agricultural Practice). Several legal initiatives had been started in 2007 and 2008 throughout Europe:

- On 23 January 2008, the European Commission tabled a proposal for a "Directive on the promotion of the use of energy from renewable sources" (*Renewables Directive* – RE-D – COM(2008) 19 final) with sustainability criteria for biofuels covering the environmental and partly the social domain. On 17 December 2008, the RE-D was adopted in first reading by the European Parliament.
- On 5 December 2007, the German Federal Government has proposed an Ordinance on criteria for the sustainable production of biomass for use as transportation fuel (*Biokraftstoff-Nachhaltigkeitsverordnung* – *Biokraft-NachV*). However, the notification process has been halted by the European Union in light of the *EU Renewables Directive*. A new version coherent to the EU RE-D shall be voted in the first half of 2009 to be enacted on 1 January 2010.

- Further EU member states and regulatory bodies, like the UK RTFO and the Comité Européen de Normalisation (CEN), have developed actions to define sustainability criteria for biomass based fuels alike.

Following the final vote on the European Directive, which is foreseen for May 2009, it can be expected that coherent requirements will be established throughout EU-27.

3 Sustainability Due Diligence

Given the complex nature of innovation and the diverse impacts novel technologies have – intended and unintended – LBST has developed *Sustainability Due Diligence* as a comprehensive approach to the subject. Fuel cultivation, production and distribution are assessed comprehensively against the legal and different sets of voluntary requirements. Figure 1 gives an overview of legal and voluntary sustainability criteria. In first applications, *LBST Sustainability Due Diligence* has already proven to be an efficient and robust tool in the project development and investment decision process, especially in view of the forthcoming biofuel certification according to the *EU RE-D*.

3.1 Greenhouse gas emissions

Greenhouse gas reductions of biofuels, hydrogen and electricity compared to conventional transport fuels have large bandwidths. A 100% reduction is feasible if renewable power or suitable biomass pathways are used. Unfavourable biomass pathways provide only insignificant greenhouse gas emission reductions compared to oil-based fuels (see Figure 2 based on analyses by the authors [1]). Including land-use changes can drive up GHG emissions to levels significantly above conventional fuels. The RE-D states a prohibition to use areas with "high carbon stock", i.e. forests of certain nature.

3.2 Land-use competition

Renewable hydrogen and electricity require significantly less land area than any biofuel production pathway, which often strongly compete with food, feed, and biomass for the production of construction material. Renewable electricity and hydrogen production can use land that is not suitable for any of these or allows for co-existence with agriculture, livestock, and forestry (Figure 3).

Those fuels offering the lowest yields per hectare also provide the lowest mileage, i.e. km travelled per MJ of fuel (Figure 4) as they are used in internal combustion engines less efficient compared to a fuel cell or even a battery electric vehicle. Yield figures are calculated based on German conditions – except for algae –, i.e. giving more optimistic results for biomass based fuels and rather conservative results for electricity and hydrogen as transport fuel. It has to be noted that significantly higher yields are sometimes claimed for algae – sometimes even exceeding the theoretical limits.

The biofuels potential in the EU is hardly sufficient to meet the non-mandatory European biofuels target for 2010 of 5.75% (Figure 5 and Figure 6). Subject to the final vote on the EU Renewables Directive, the proposed 10% target by 2020 would further increase the market pull on biofuel exporting countries like Brazil, Indonesia, Malaysia and African countries.

Yield and potential analyses are based on detailed analyses carried out by the authors [1], [2], [3]. Because of competition with stationary energy uses only 50% of the technical potentials may be available for transport. Around 50% of the land area of Africa would be required to substitute today's global mineral oil consumption by palm oil (compared to 7% arable land in Africa), while hydrogen from PV would only require 5-6%.

Food competition is a complex issue that is difficult to deal with at the level of individual cultivation projects and thus requires a more comprehensive approach. The competition issues is often accompanied with or related to social issues like extensive farming for subsistence living of the local population, e.g. on supposedly 'abandoned' lands, as well as legal matters like land titles and ownership. Satisfactory solutions are yet to be developed.

3.3 Water intensity

Analyses based on average or typical values of water requirements show that biofuels production in general consumes several orders of magnitude more water than electrolytic hydrogen production, or electricity generation from solar thermal power plants (see Table 1). This is aggravated if inefficient irrigation systems are used for cultivation (flood, spray, furrow and drip irrigation in increasing order of efficiency). The agricultural sector is responsible for some 60% of world water consumption. Sea water desalination for electrolytic hydrogen production only requires 0.13%-0.16% of the power consumption of the electrolysis process itself [4], [5]. "Grey waters", i.e. water consumed in manufacturing the production machinery and infrastructure have not been taken into account. It is assumed that they are negligible, similar to "grey energies".

3.4 Preserving biodiversity

The impact of biofuels on biodiversity is subject to the individual situation on the area before establishment of the cultivation, and to plantation management, such as the plantation setup (monoculture versus intercropping versus succession), as well as the use of fertiliser, herbicides and pesticides etc. Biodiversity impacts have to be assessed on the basis of comprehensive individual onsite analyses and with a view to overarching habitat and use patterns in the greater project area in order to preserve both sufficiently sized remaining habitats that are furthermore sufficiently close and well connected through migration routes for both flora and fauna. Special attention has to be given to the occurrence of endemic species.

Impact mitigation measures can be developed, e.g. minimising the loss of rare species through careful timing or even replacement programmes before the land clearing for field preparation.

The RE-D prohibits the use of areas with "high conservation value".

3.5 Social impacts, local economy and development

Like many economic activities, biofuels can have very positive impacts towards a number of development goals, especially through increasing local economic prosperity that goes along with regular, paid labour. This is especially true for marginalised communities. On the other hand, negative impacts have been reported where established traditional land uses of the local population are suppressed through the occupation of large land areas for biofuels production at the expense of subsistence farming.

Large-scale biomass cultivation for biofuel production in rural areas may dominate the local economy, making it vulnerable to incidents like pests, natural disasters, or changes in the world market. Allowing other local businesses to remain in place or even fostering their development is thus of utmost importance.

Legal requirements that go beyond the criteria set of the International Labour Organization (ILO) would likely not comply with WTO/GATT rules. To this end, the RE-D states a reporting obligation on social issues.

4 Conclusions

From the assessment of alternative transportation fuels and their use in different propulsion systems (internal combustion engine, fuel cell, plug-in hybrid) against key sustainability criteria, it can be concluded that

- greenhouse gas reductions attributable to biofuels, hydrogen and electricity have large bandwidths from 100% reduction to even significant increases in greenhouse gas emissions compared to conventional fuels;
- hydrogen and renewable electricity perform significantly superior to any of the biofuel production pathways with respect to land-use intensity and tank-to-wheel energy consumption; in addition, biofuels production often strongly competes with food production whereas renewable electricity and hydrogen production can use vast land areas not suitable for food production, or in the case of wind power for electricity or hydrogen production does not occupy the land; detailed analyses of total fuel production potentials for the European Union lead to 2% (plant oil based fuels) to a maximum of 20% (hydrogen from biomass) transport fuel replacement potentials;
- biofuels' water requirements provide for a broad bandwidth with strong sensitivities regarding local climatic conditions; analyses based on average or typical values show that biofuels production in general consumes several orders of magnitude more water than hydrogen production from photovoltaics or wind, or electricity from solar thermal power plants; and
- social impacts, local economy and development as well as food competition are very complex issues that are difficult to be sufficiently dealt with on project level, and hence require a local political framework to catalyse the interests of regional, national and international stakeholders.

Full life-cycle analyses based on all sustainability criteria are required for assessing the sustainability of alternative transportation fuels. The results presented here show that the hopes presently put on biofuels are exaggerated and pose serious environmental and social risks. Electricity and hydrogen as transport fuels in contrast can achieve full sustainability goals quantitatively and qualitatively if based on renewable energies.

Figures

LBST Nomenclature of sustainability criteria

Area	Theme	Subject
1. Environmental	1.1 Climate	1.1.1 GHG balance
		1.1.2 Carbon sinks
	1.2 Biodiversity	1.2.1 Biodiversity
	1.3 Local environmental effects	1.3.1 Air quality
		1.3.2 Soil quality, erosion
		1.3.3 Water quality and resources management
2. Social	2.1 Social well-being	2.1.1 Social well-being of employees and local population
		2.1.2 Health and safety
		2.1.3 Pay and conditions for employees, trade unions
		2.1.4 No child employment
		2.1.5 No discrimination
		2.1.6 Women's rights
3. Economic	3.1 Local economic effects	3.1.1 Local prosperity
	3.2 Economic sustainability	3.2.1 Long-term economic and financial viability
4. Other	4.1 Competition with food/ other indirect effects of land use change	4.1.1 Food competition
	4.2 Governance	4.2.1 Transparency, stakeholder participation
		4.2.2 Compliance with applicable laws, regulations and customary rights
		4.2.3 Land use rights
		4.2.4 Documentation, implementation, monitoring
		4.2.5 Training
		4.2.6 Environmental and Social Impact Assessment for Planning and Implementation
		4.2.7 Continuous improvement in social and environmental aspects
		4.2.8 Criteria conformance and corrective action
	4.3 Good Agricultural Practice	4.3.1 Minimum level of maintenance
		4.3.2 Integrated pest management
		4.3.3 Use of agrochemicals
		4.3.4 Waste reduction, recycling, re-use, disposal
	4.4 Biotechnology	4.4.1 Genetically modified organisms
Certification Procedures	Supply Chain Options	Chain of Custody (segregation, mass balance), Book & Claim
Scope	Geographic	
	Sectoral	

Figure 1: LBST nomenclature for sustainability criteria

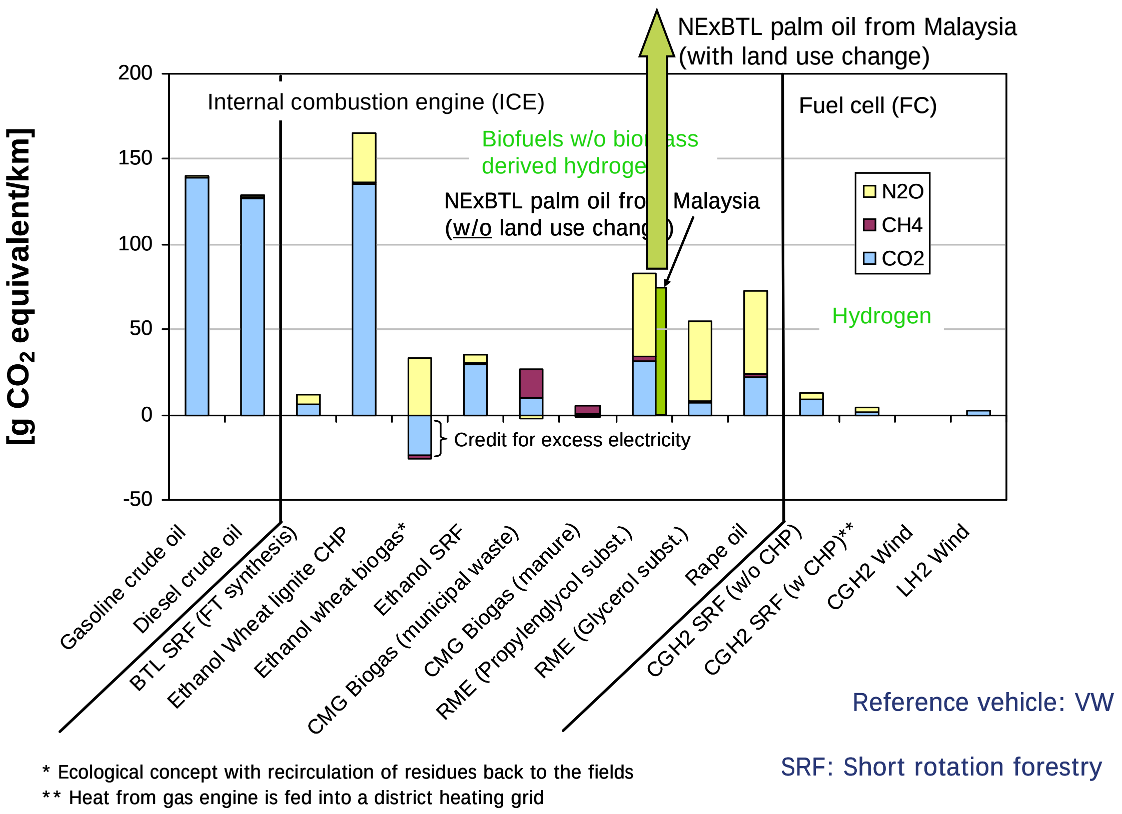

Figure 2: GHG emissions "well-to-wheel" (VW Golf) excluding land use change emissions
(palm oil emissions are up to 25 times diesel emissions if land use change is considered)

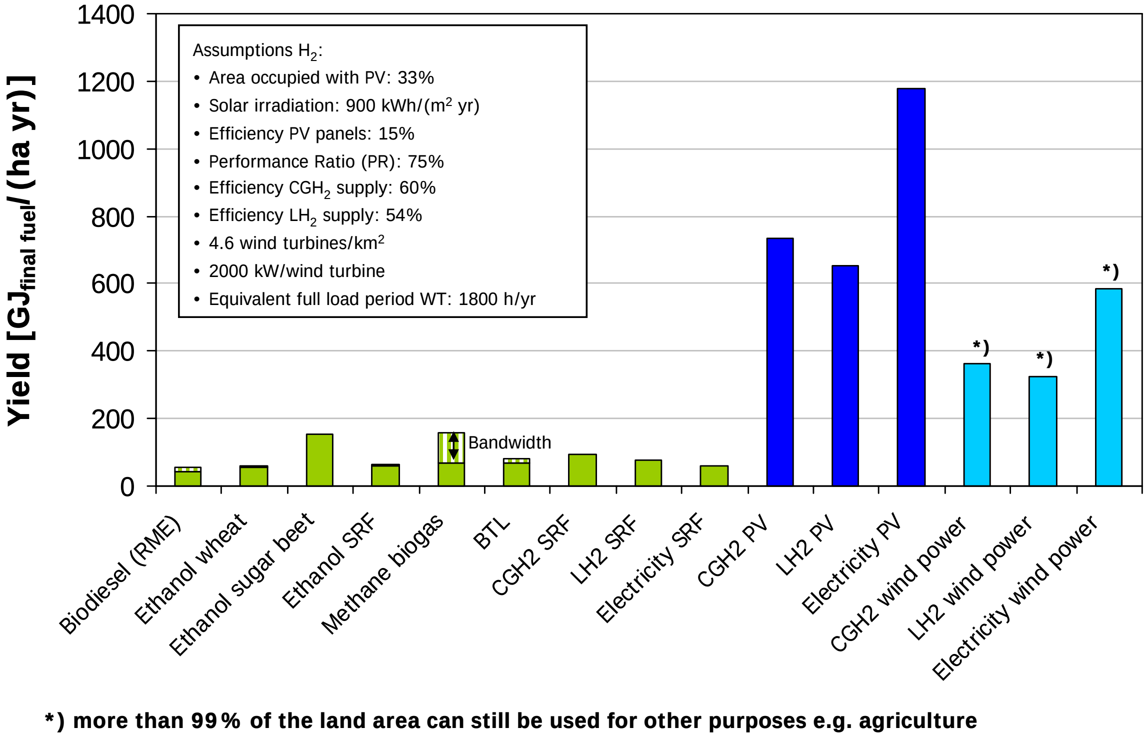

Figure 3: Yield of biofuels compared to hydrogen produced from wind power or PV

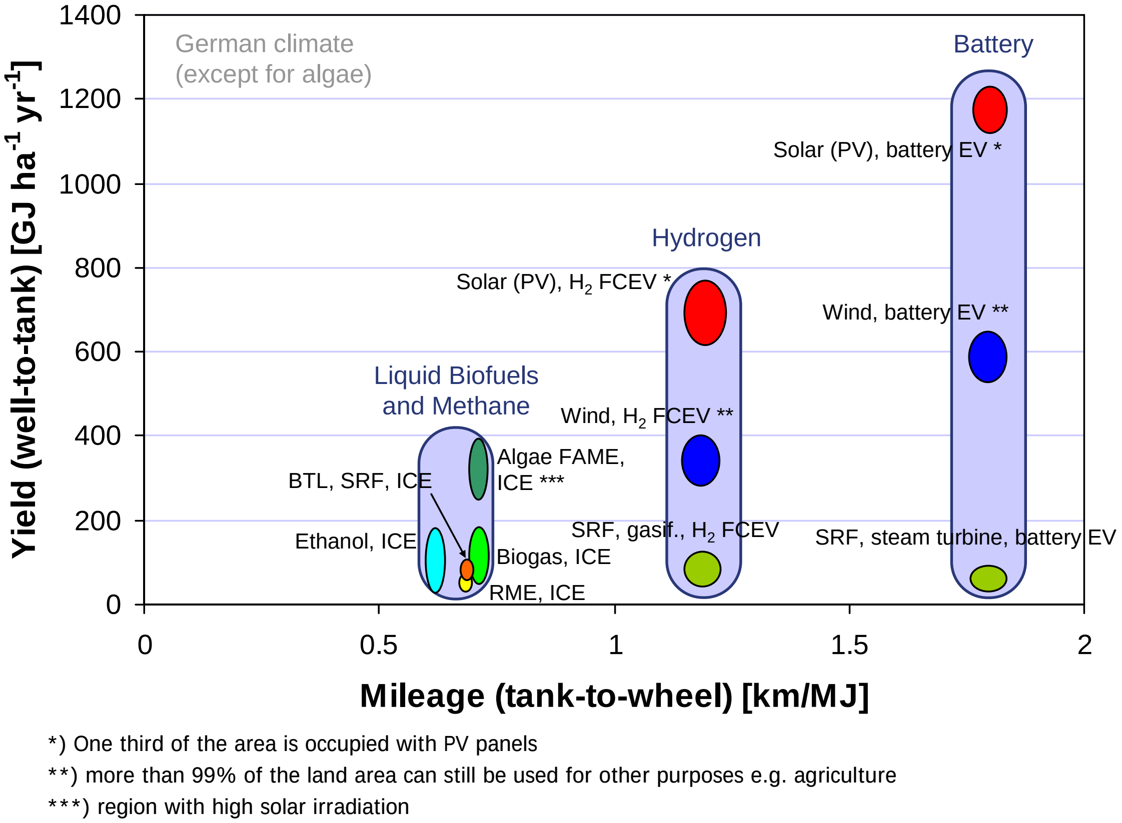

Figure 4: Mapping of key performance criteria “mileage” versus “yield” under German conditions (except for algae)

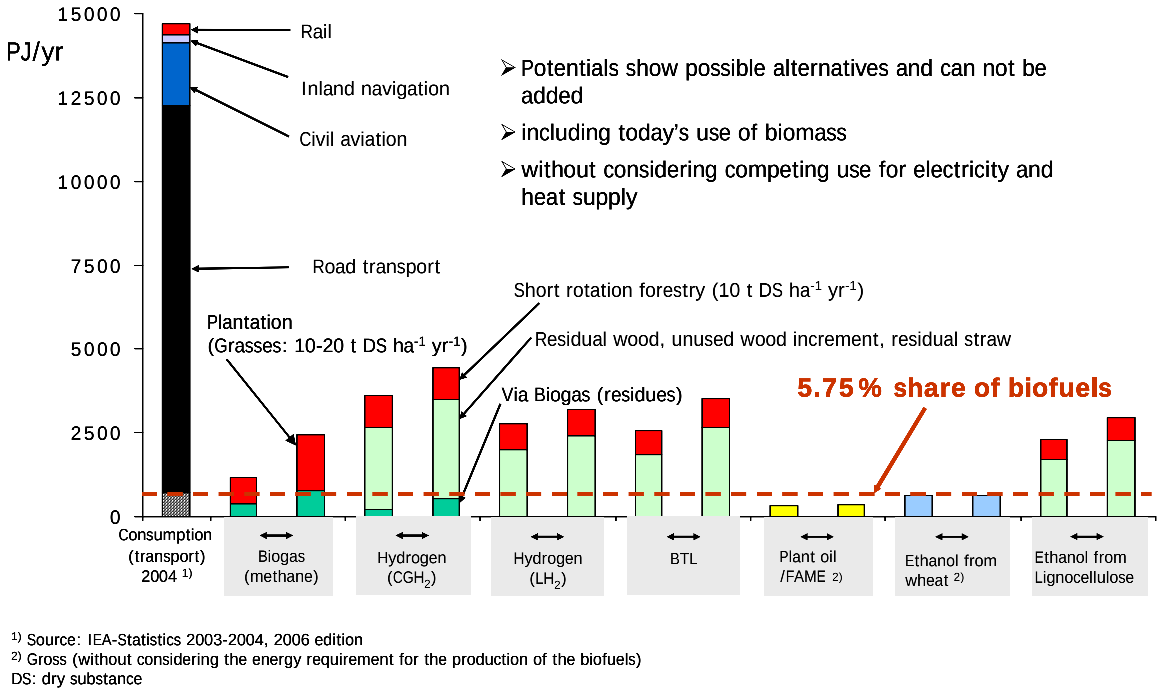

Figure 5: EU-27 technical potential for biomass derived fuels [3]

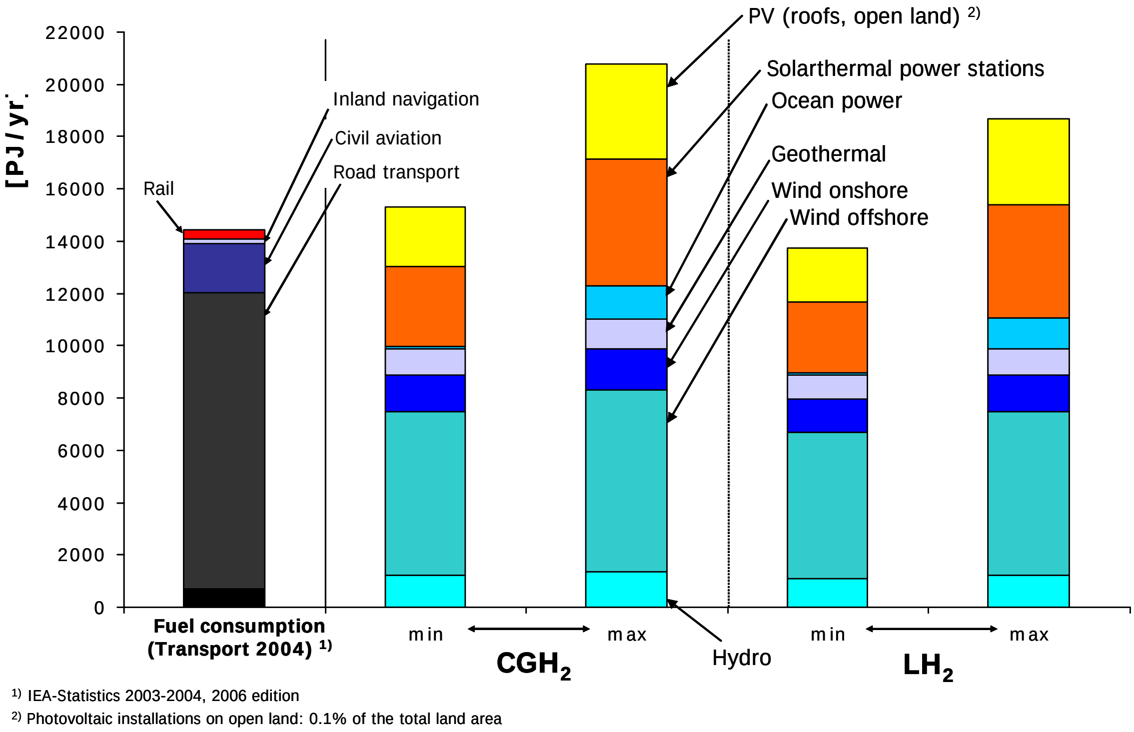

Figure 6: EU-27 technical potential for hydrogen from renewable electricity [3]

Table 1: Water requirement for the cultivation of various crops used for biofuels, for electrolytic hydrogen production and for renewable electricity generation

Crop	Region	Water requirement [kg/kg_{crop}]	Final fuel	Water requirement [$kg/MJ_{final\ fuel}$]
Corn	USA	1400	Ethanol	157 1)
Soybean	USA	2000	FAME	291 1)
Sugar cane	e.g. Brazil	1500-3000	Ethanol	772-1544 1)
Wheat	e.g. EU	900	Ethanol	115 1)
Jatropha	India	625-1875	FAME	47-140 1)
Hydrogen from PV	Pakistan	–	Hydrogen	0.75 2)
PV or wind power	Worldwide	–	Electricity	0
Solar thermal power plant	Morocco	–	Electricity	0.28-1.25 3)

1) Cultivation of the energy crops
2) Water for hydrogen production via electrolysis
3) Lower and upper values assuming dry cooling and wet cooling, respectively [6]

Acronyms and Abbreviations

GATT – General Agreement on Tariffs & Trade
GHG – Greenhouse Gas
GlobalGAP – Global Partnership for Good Agricultural Practice
ILO – International Labour Organization
PV - Photovoltaics
RE-D – European Union Renewables Directive
RSPO – Roundtable for Sustainable Palm Oil
FSC – Forest Stewardship Council
WTO – World Trade Organization

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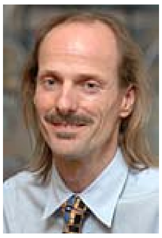
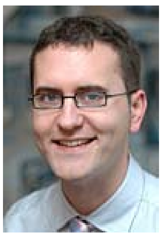


Werner Weindorf holds a Degree in Physics from Munich University of Applied Sciences. Since 1998 he is with LBST working on life-cycle analyses with the LBST proprietary E3database.



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