Biofuels Sustainability – Focus on Lifecycle Analysis · Ispra/Italy · 16 May 2019

LCA parameters which cause large deviations

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Agenda

- LCA parameters which cause large deviations
  - Soil N_2O
  - Land use change
  - GWP factors
  - CO_2 sources for power-to-methane and power-to-liquid

Soil N_2O emissions

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- Large bandwidth for soil N_2O-emissions according to 2006 IPCC Guidelines

Code		Unit	Default	Min	Max
EF_1	Direct N_2O	kg N_2O-N/(kg N-input)	0.01	0.003	0.03
EF_4	Indirect N_2O from NH_3-N and NO_x-N	kg N_2O-N/(kg NH_3-N and NO_x-N)	0.010	0.002	0.05
EF_5	Indirect N_2O from leaching N	kg N_2O-N/(kg N leaching/runoff)	0.0075	0.0005	0.025
$Frac_{GASF}$	Volatilization from synthetic fertilizer	kg (NH_3-N + NO_x-N)/kg of synthetic fertilizer-N	0.100	0.03	0.3
$Frac_{LEACH}$	N losses by leaching/runoff	kg N/kg of synthetic fertilizer-N	0.300	0.1	0.8

Soil N_2O emissions

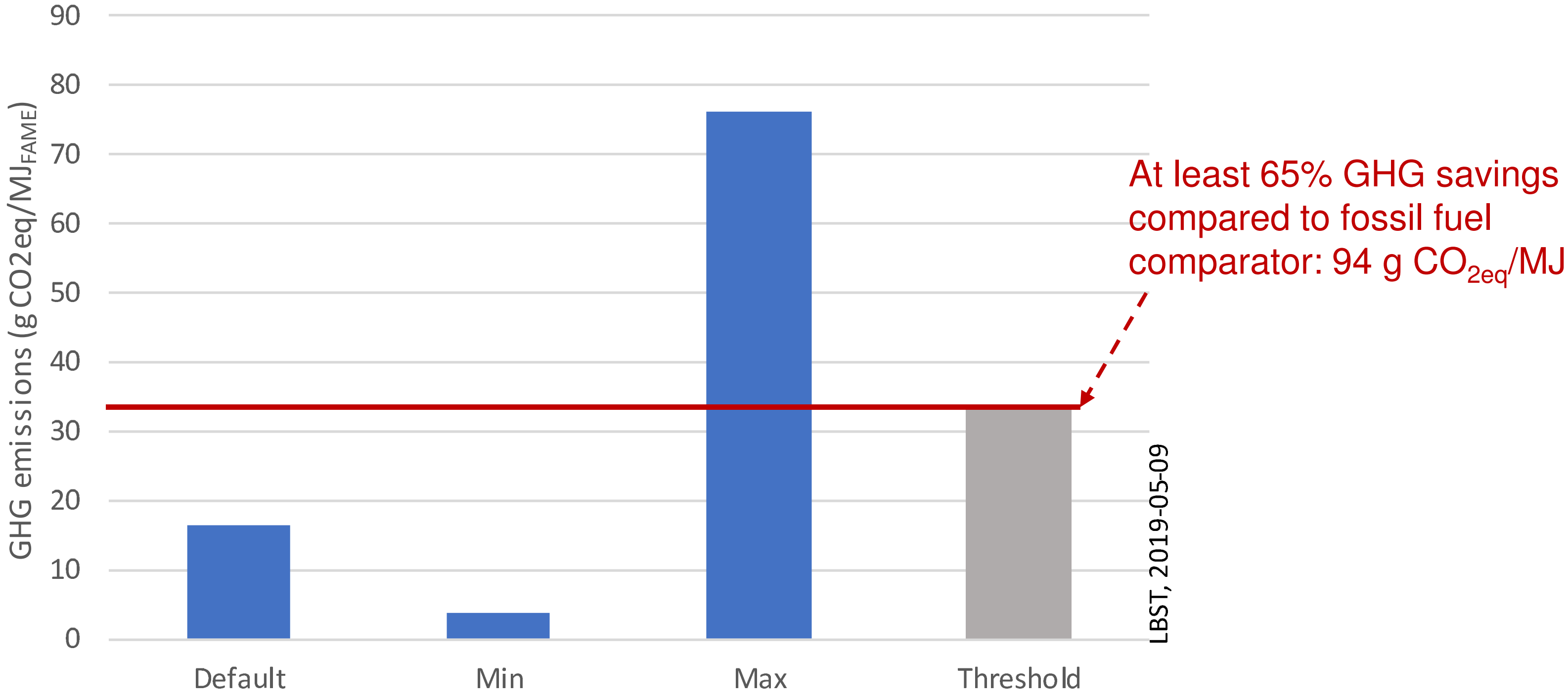
- Comparison of results for FAME from rapeseed as an example

	Unit	Default	Min	Max
Crop yield	t_{moist}/(ha*yr)	3.15		
Fertilizer input	kg N/(ha*yr)	142		
Direct N_2O	kg N_2O-N/(ha*yr)	2.12	0.64	6.37
Indirect N_2O from NH_3 and NO_x emissions	kg N_2O-N/(ha*yr)	0.14	0.01	2.13
Indirect N_2O from N leaching/runoff	kg N_2O-N/(ha*yr)	0.48	0.01	4.25
Total	kg N_2O-N/(ha*yr)	2.74	0.66	12.75
Soil N_2O emissions	g N_2O/MJ_{FAME}	0.0550	0.0132	0.2557
	g CO_{2eq}/MJ_{FAME}	16.4	3.9	76.2

- Large deviations due to deviations of soil N_2O emissions

Soil N_2O emissions

- Comparison of results for FAME from rapeseed as an example



- Soil N_2O emissions alone can exceed the threshold for overall GHG emissions for biofuel supply in the recast of the Renewable Energy Directive

Impact of soil N_2O emissions, production of agrochemicals, and diesel use

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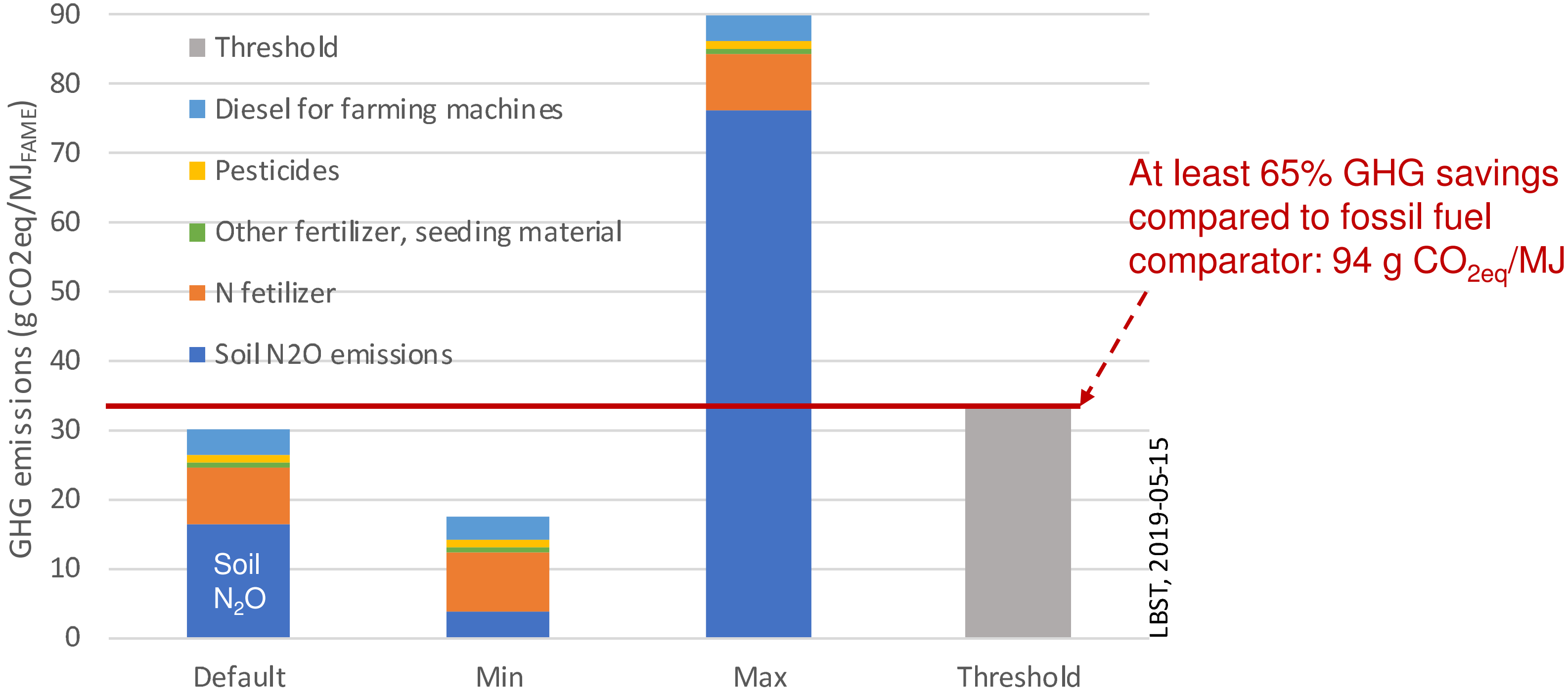
- Comparison of results for FAME from rapeseed as an example



- In case of default soil N_2O emissions GHG emissions from cultivation limit the GHG savings to about 68%

Soil N_2O emissions in the EU

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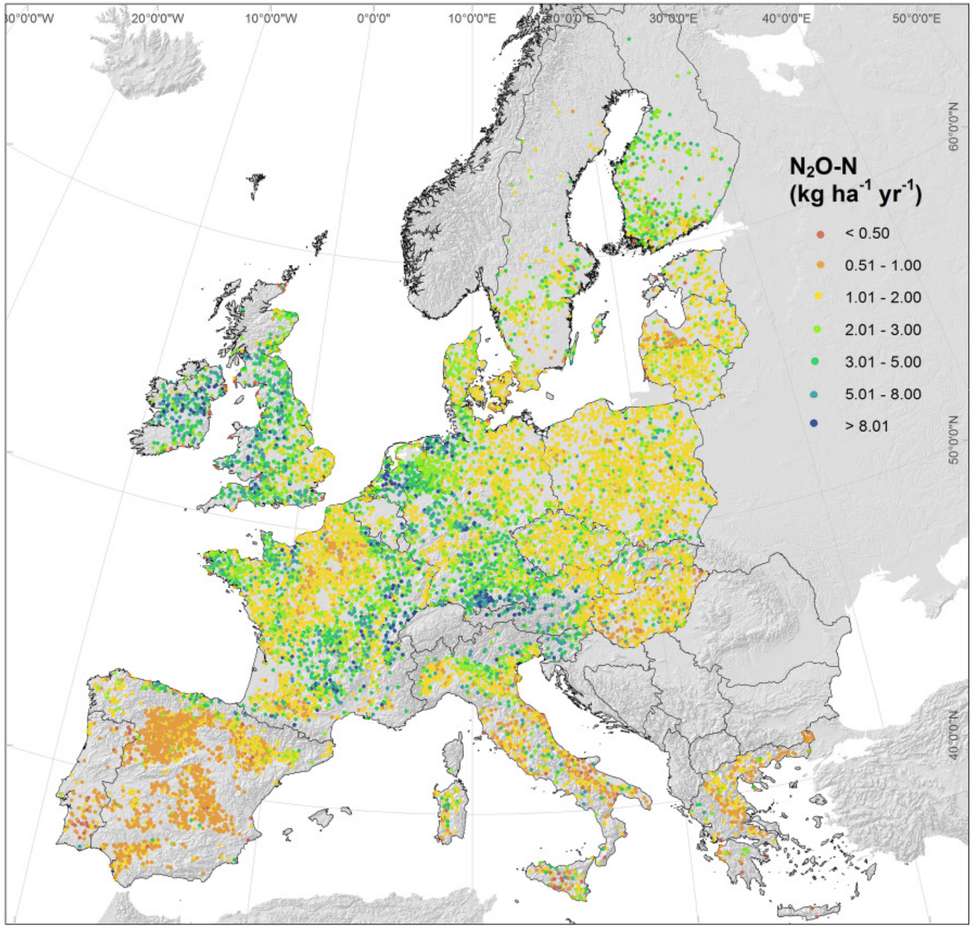
- Median value:
  1.71 kg N_2O-N/(ha*yr)
- Large deviations between the different regions from less than 0.50 to more than 8.01 kg N_2O-N/(ha*yr)



Reference:
Lugato E, Paniagua L, Jones A, de Vries W, Leip A (2017) Complementing the topsoil information of the Land Use/Land Cover Area Frame Survey (LUCAS) with modelled N_2O emissions. PLoS ONE 12(4): e0176111. https://doi.org/10.1371/journal.pone.0176111

Uncertainty of soil N_2O emissions in the EU

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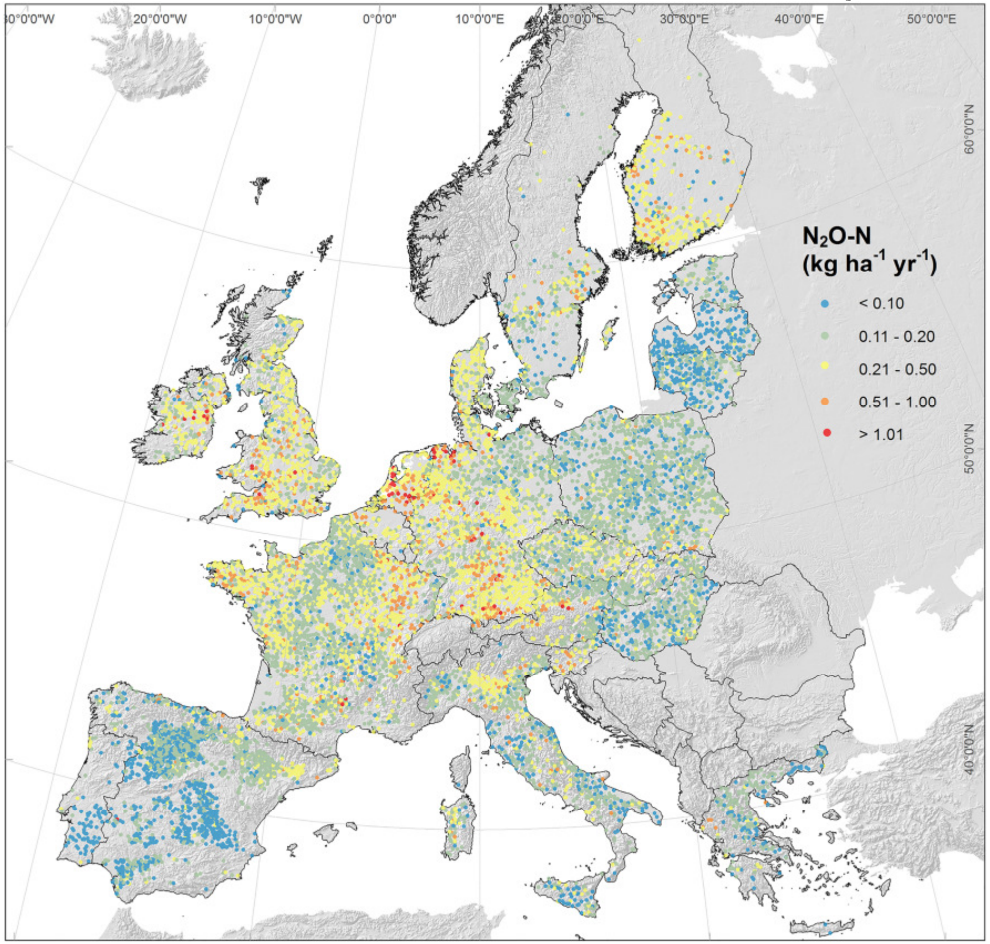
- Uncertainty: 10 to 20% within a dedicated region



Reference:
Lugato E, Paniagua L, Jones A, de Vries W, Leip A (2017) Complementing the topsoil information of the Land Use/Land Cover Area Frame Survey (LUCAS) with modelled N_2O emissions. PLoS ONE 12(4): e0176111. https://doi.org/10.1371/journal.pone.0176111

Land use change

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- CO_2 emissions from land use change (LUC) can have a significant impact on the overall GHG footprint of biofuels
- CO_2 emissions from LUC occur:
  - Removal of aboveground biomass
  - Oxidation of carbon in the soil
  - Peat fires
- Large bandwidth e.g. for CO_2 emissions from LUC for oil palm grown on peatlands
- The assessment of indirect land use change (ILUC) is very difficult

Land use change

- GHG emissions from LUC for oil palm grown on peatlands based on [Hashim et al. 2017]
  - Degraded peatland (grassland)
  - Lightly logged-over peat swamp forest

	Carbon stock	CO_{2eq} emissions	
	(t C/ha)	(t /(ha*yr))[a]	$(g/MJ_{FAME})^b$
Aboveground biomass	13-180	-3.2 to 21.3	-30 to 195
Peat oxidation		13 to 53	119 to 486
LUC total		9.8 to 74.3	90 to 681

a: Growing period: 25 yr: Carbon stock oil palm: 35 t/ha
b: 15.1 t FFB/(ha*yr); 0.2 t CPO/(t FFB)

- LUC alone can lead to extremely high CO_2 emissions of more than seven times of the GHG emissions of the fossil fuel comparator in the recast of the RED (94 g CO_{2eq}/MJ)

GWP factors

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- The global warming factors (GWP) have changed from the IPCC forth assessment report (AR4) to the fifth assessment report (AR5)

	AR4 (g CO_2 equivalent/g)	AR5 (g CO_2 equivalent/g)
CO_2	1	1
CH_4	25	30
N_2O	298	265

- Example FAME from rapeseed: AR5 leads to 8% less GHG emissions from combined soil N_2O emissions and fertilizer supply compared to AR4 if IPPC default values are applied for soil N_2O

CO_2 source for $PtCH_4$ and PtL

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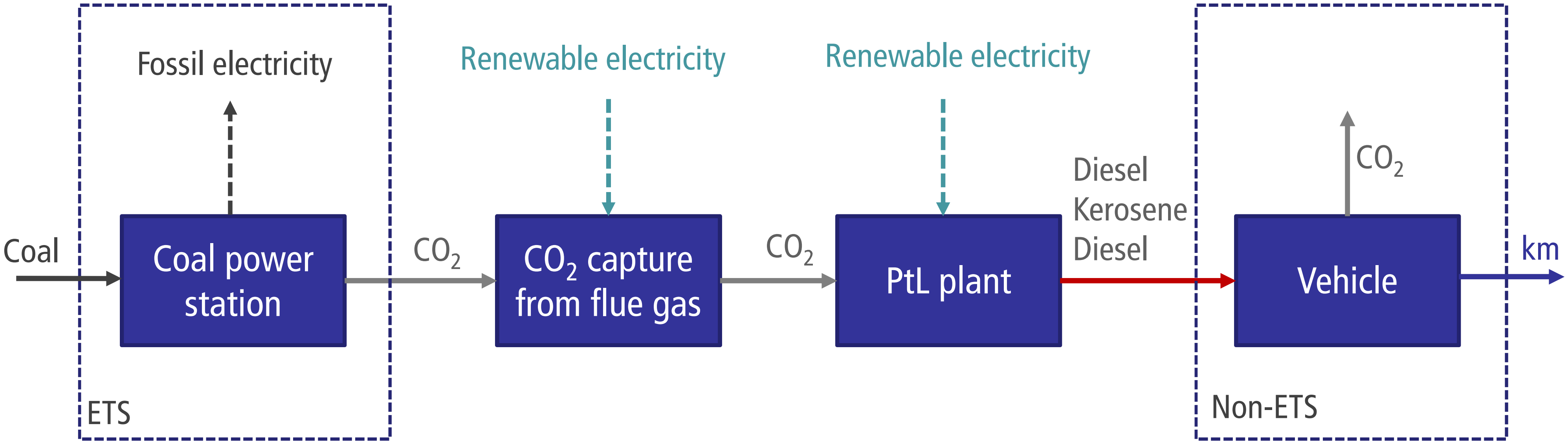
- Technologies
  - CO_2 from biogas upgrading
  - Direct methanation of CO_2 in crude biogas stream
  - CO_2 from industrial waste gases e.g. calcination (CaO production)
  - CO_2 from flue gases
  - Direct air capture (DAC) of CO_2
- CO_2 from flue gases
  - CO_2 from biomass combustion: CO_2 neutral
  - CO_2 from fossil fuel combustion: Fossil CO_2 is emitted
- How to allocate fossil CO_2 used for fuel production?
- How to take into account lock-in effects?

CO_2 from fossil fuel combustion for $PtCH_4$ and PtL

- CO_2 from concentrated fossil fuel combustion used for fuel production means shifting CO_2 emissions from the ETS sector (e.g. power stations) to the non-ETS sector (e.g. road transport)



CO_2 supply | Concentrated sources & sustainability

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- Not all CO_2 sources are equally sustainable:

CO_2 sources	Environm. sustainability	Alternative CO_2 uses	Towards carbon-neutrality
Extraction from air	Subject to electricity source		
Biogas upgrading	Subject to feedstock & process	Synthesis with PtH_2	Other biomass uses
Solid biomass fired heat (and power) plants	Subject to feedstock & process	Bio-CCS	Other biomass uses
Fermentation to alcohols	Subject to feedstock & process	Mineral water, tap bev's, Coke	Other biomass uses
Geothermal sources	Subject to geo-phys. CO_2 cycle	CO_2 re-injection (closed-loop)	Hot dry rock a potential no-go
Cement production	What level is 'unavoidable'?	Power-to-chemicals	Shift to alternative materials
Steel production	Short-term exemptions?	Top-gas for heating&reduction	Shift to direct reduction w/ H_2
Fossil fuel firing	Short-term exemptions?	CCS	Phase-out, technology lock-in

LBST, 2017-04-07

- Sustainability safeguards are necessary to avoid unintended collateral damages, such as the lock-in of fossil technologies.
- A robust sustainability framework is furthermore important to give stakeholders the confidence for building value chains (bankability), e.g. regarding CO_2 burden sharing (no leakage into unregulated sectors).

Reference: Schmidt, P.R. (LBST), Batteiger, V. (BHL), et al., Power-to-Liquids as Renewable Fuel Option for Aviation: A Review, CIT, January 2018

References

- [Hashim et al. 2017] Hashim, Z.; Subramaniam, V.; Harun, M., H.; Kamarudin, N.: Carbon footprint of oil palm planted on peat in Malaysia; The International Journal of Life Cycle Assessment, Springer-Verlag GmbH Germany 2017, DOI 10.1007/s11367-017-1367-y
- [IPCC 2006] Paustian, K., et al: 2006 IPCC Guidelines for National Greenhouse Gas Inventories; IPCC National Greenhouse Inventories Programme; published by the Institute for Global Environmental Strategies (IGES), Hayama, Japan on behalf of the Intergovernmental Panel on Climate Change (IPCC), 2006; http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4
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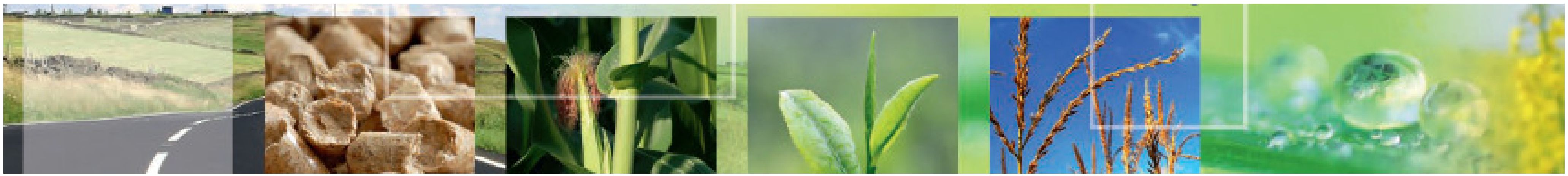

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Profile

- Independent expert for sustainable energy and mobility for over 30 years
- Bridging technology, markets, and policy
- Renewable energies, fuels, infrastructure
- Technology-based strategy consulting, System and technology studies, Sustainability assessment
- Global and long term perspective
- Rigorous system approach – thinking outside the box
- Serving international clients in industry, finance, politics, and NGOs

References

- JEC – *Well-to-Wheels Study*
- Fondation Tuck – *Future Fuels for Road Freight*
- VDA – *E-Fuels Study*
- UBA – *Power-to-Liquids for Aviation*
- EC – *CertifHy – EU green H_2 guarantee of origin scheme*

Water demand

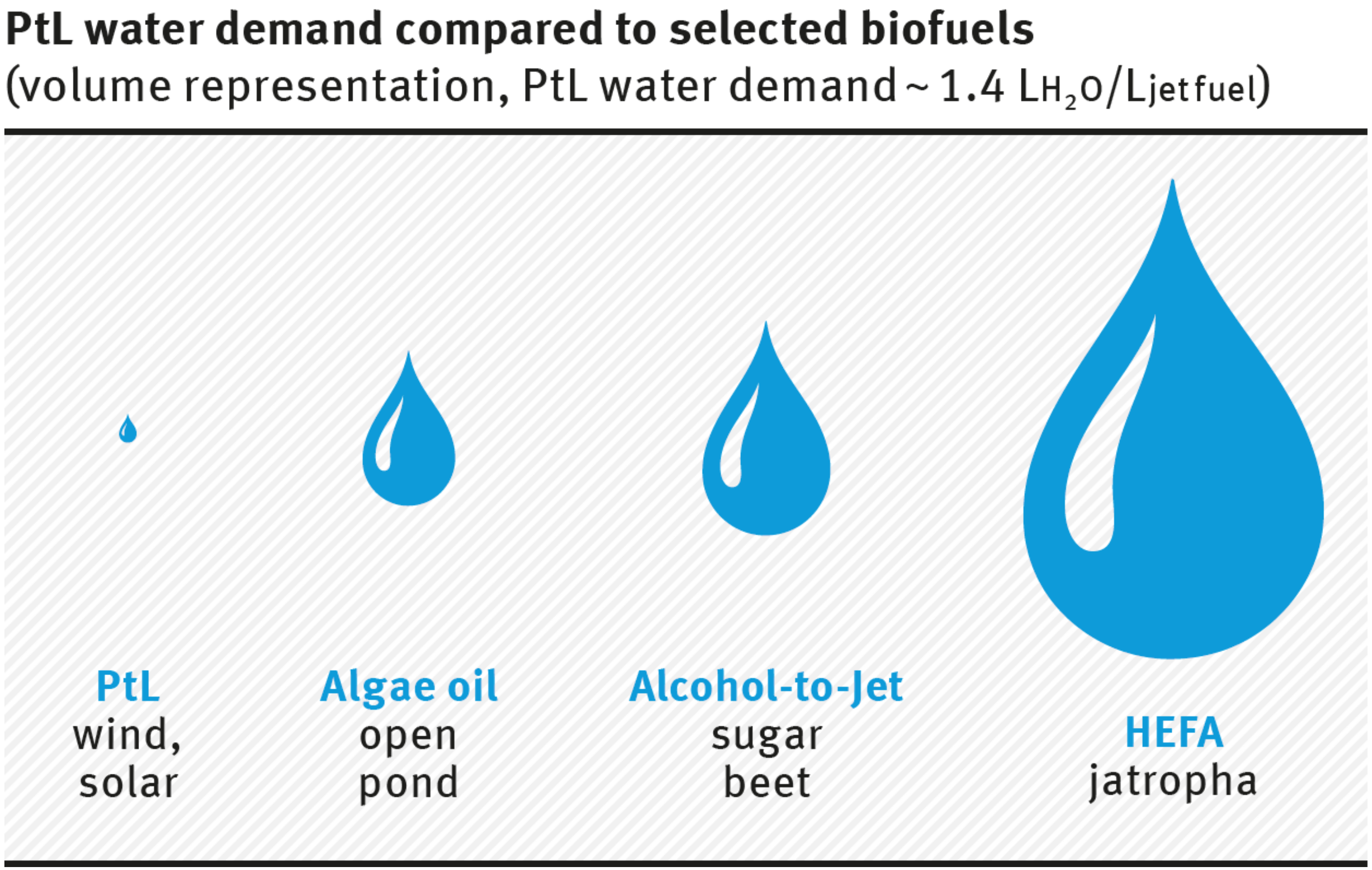
Water demand for biofuel and power-to-fuels production

Feedstock/pathway	Green water (m^3/GJ)	Blue water (m^3/GJ)	Sum (m^3/GJ)	Sum ($l_{H_2O}/l_{jet\text{-}fuel\text{-}eq}$)	Reference
Jatropha oil	239	335	574	19914	Weighted global Ø (JRC 2013)
Rapeseed oil	145	20	165	5724	
Soybean oil	326	11	337	11691	
Palm oil	150	0	150	5204	
Sunflower oil	428	21	449	15577	
Ethanol from maize*	94	8	102	3539	
Ethanol from sugar beet*	31	10	41	1422	
Ethanol from sugar cane*	60	25	85	2949	
BtL from poplar**	107	6	112	3892	(Jungbluth et al 2007)
Algae oil (open pond with water recycling)**	0	14	14	497	(Stephenson 2010)
Algae oil (open pond w/o water recycling)**	0	53	53	1839	
PtG hydrogen (wind, PV)	0	0.076	0.076	2.63	This study (LBST)
PtL via FT pathway (wind, PV, CSP***)	0	0.040	0.040	1.38	
PtL via methanol pathway (wind, PV, CSP***)	0	0.038	0.038	1.33	

Green water: Precipitation on land that is stored in the vegetation, in the soil, or stays on top of the soil
Blue water: Water consumption from surface and groundwater
* Similar performance assumed as for direct sugar-to-hydrocarbons conversion, e.g. Amyris-Total 'Farnesane'
** In moderate climate zones, e.g. Europe, Northern USA, Southern Canada
*** Concentrated solar power via solar-thermal steam turbine with dry cooling system

Reference: LBST & BHL, Power-to-Liquids for Aviation; German Environment Agency (ed.), September 2016

Water demand



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