CO_2-based Aviation Fuels the best option available

ONLINE
1st European Summit on CO_2-based Aviation Fuels

23 March 2020

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As an introduction, first the clearing up of a misunderstanding:

CO_2-based fuels do not make a relevant contribution to climate protection, since the CO_2 is only bound for a short time and then emitted back into the atmosphere after a short time. Only CCS can do this to reduce CO_2 concentration in the atmosphere.

This is a widespread misconception that completely overlooks the substitution effect of fossil fuels.

CCU vs. CCS

For CCU, the time span of CO_2 sequestration is not relevant – here the substitution of fossil-based products counts. **What storage is to CCS, substitution is to CCU.**

- **With CCS**, you can – in principle – capture all CO_2 emissions from fossil sources and sequester them.
- **With CCU**, you can – in principle – substitute all carbon from fossil sources (and therefore any additional fossil CO_2 emissions) through the use of renewable energies and CO_2 utilisation.

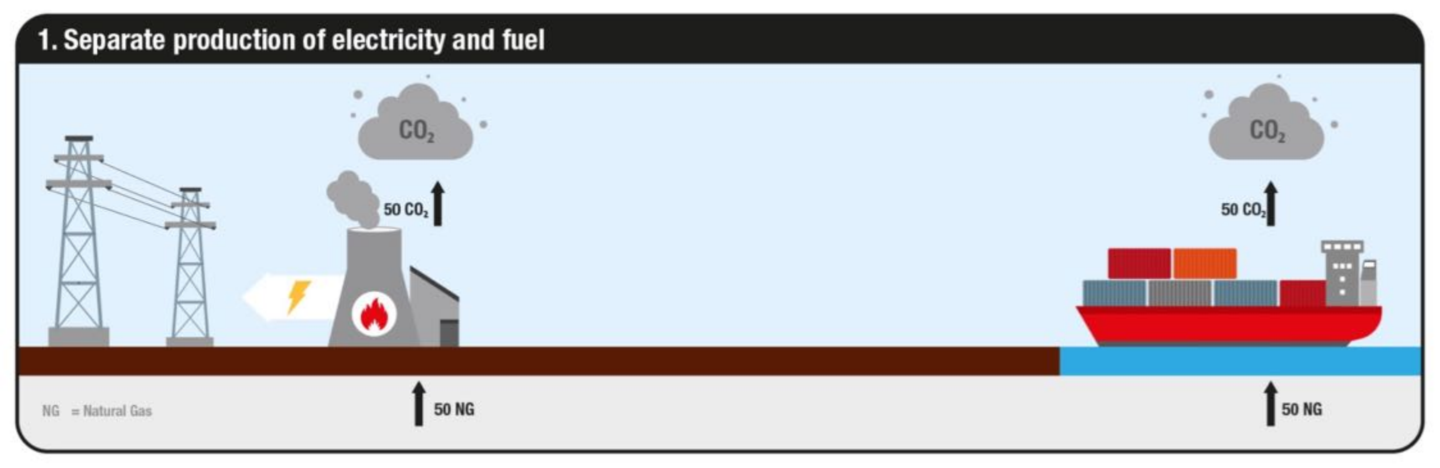
The amount is exactly the same!

Today, the remaining amount of fossil carbon is already sequestered underground in the form of oil and gas reserves:

- **CCS means**: we extract the fossil carbon, use the contained energy and then capture the CO_2 afterwards to sequester it again.
- **CCU means**: we leave the remaining fossil carbon sequestered and substitute it directly by renewable energy and CCU (for fuels, chemicals and plastics).

System expansion: Production of electricity and fuel

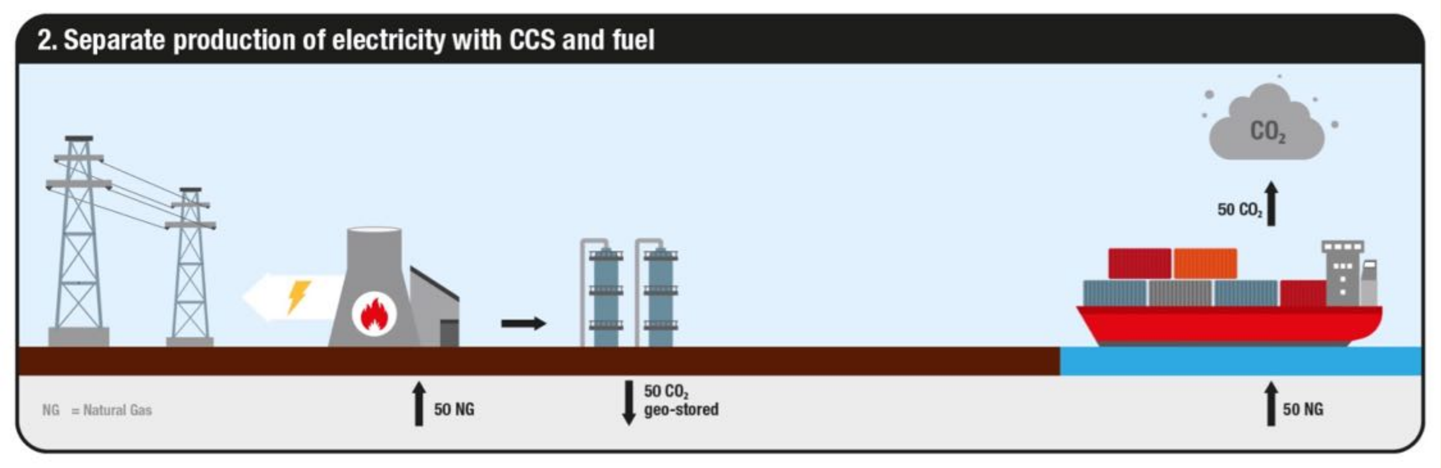
(the figures are a model for the idealized condition without losses (100% efficiency))



Separate fossil electricity and fossil fuel production result in the maximal GHG emissions (50 + 50 CO_2 = 100 CO_2)

System expansion: Production of electricity and fuel

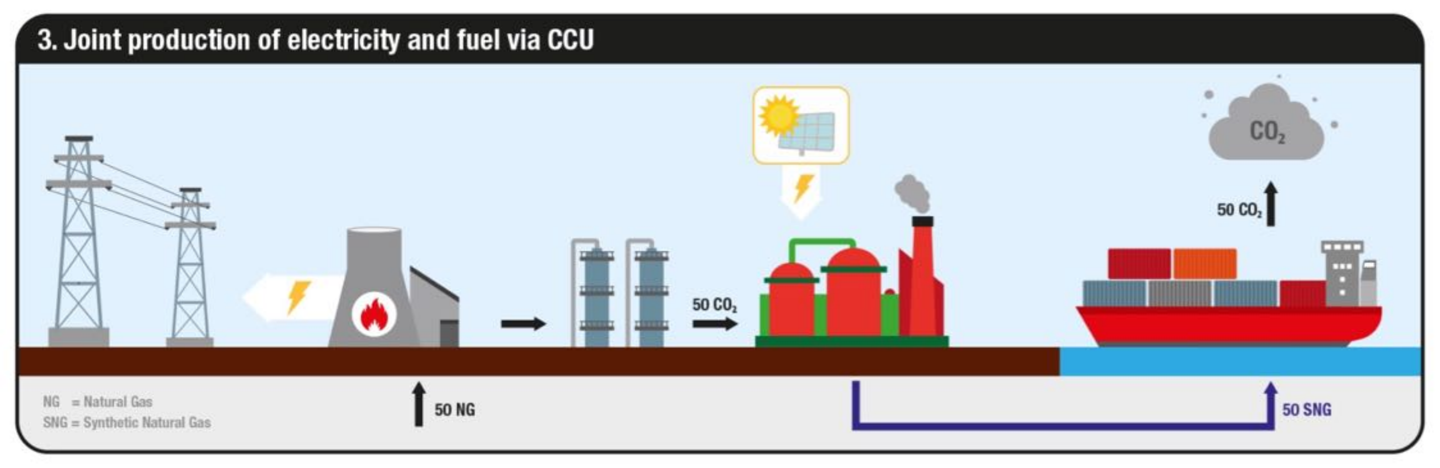
(the figures are a model for the idealized condition without losses (100% efficiency))



Carbon Capture and Sequestration (CCS) reduces the total CO_2 emissions by 50%.

System expansion: Production of electricity and fuel

(the figures are a model for the idealized condition without losses (100% efficiency))



Carbon Capture and Utilization (CCU) also reduces total CO_2 emissions by 50% by using emissions from electricity production to produce fuels and substituting fossil natural gas (NG).

All you want to know … about CCU

nova paper #11 on bio- and CO_2-based economy
2019-02

Hitchhiker's Guide to Carbon Capture and Utilisation

Authors: Michael Carus, Pia Skoczinski, Lara Dammer, Christopher vom Berg, Achim Raschka and Elke Breitmayer
nova-Institute, Hürth (Germany)

Free download at: www.bio-based.eu

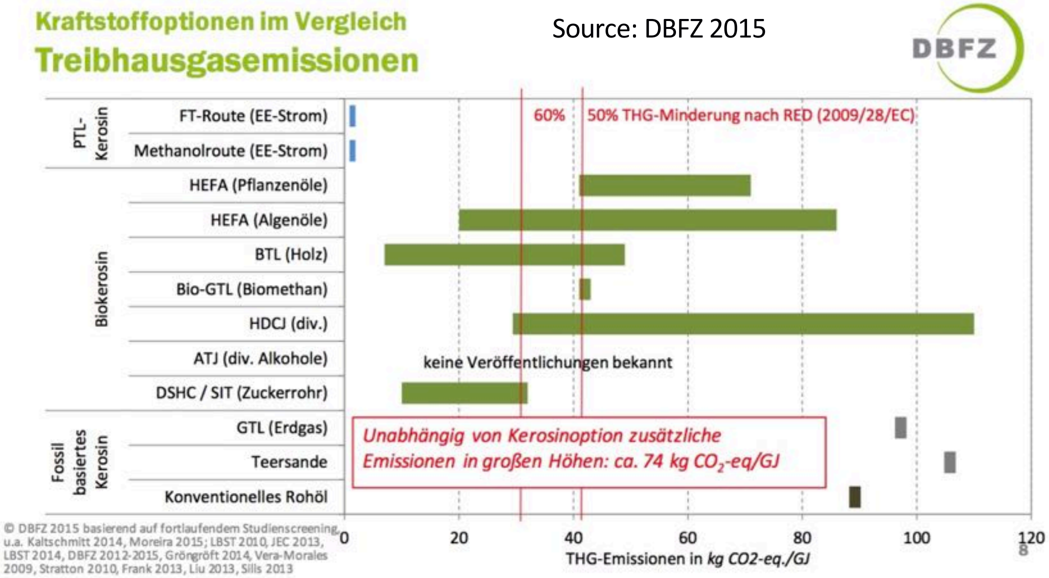
Environmental Assessment

Major threats and challenges to our planet are

- Climate change and
- Biodiversity loss

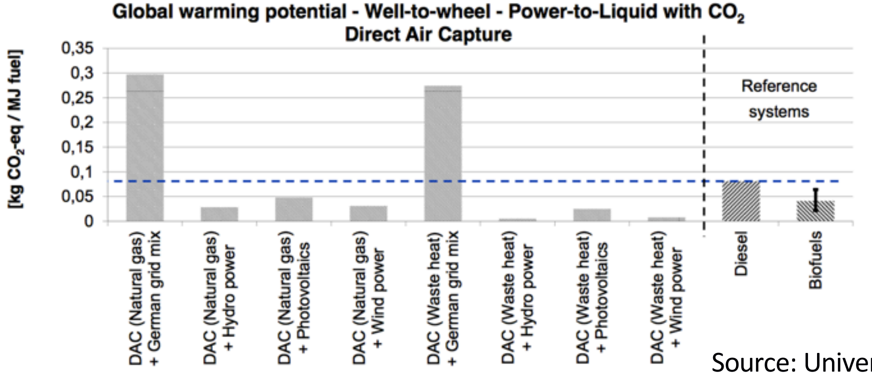
Several life cycle assessments show that the **climate footprint of solar kerosene is much better than all alternatives**. The CO_2 emissions per tonne solar kerosene are **considerably lower than those of bio-based kerosene and about 80 to 90% lower than of petrochemical kerosene**. Calculations show that compliance with the **2-degree-Celsius climate goal is only possible using solar kerosene**. In comparison to bio-kerosene, area and water demands are also much lower.

About 220,000 flights have used the fuels since 2008, which sounds like a lot until you consider that there were 39 million flights in 2019. ***Biofuel accounts for just 0.01 per cent of all aviation fuel used today***. *(NewScientist, 8 January 2020)*



Source: DBFZ 2015

Results of the combination of CO_2 Direct Air Capture and Power-to-Liquid using different power sources



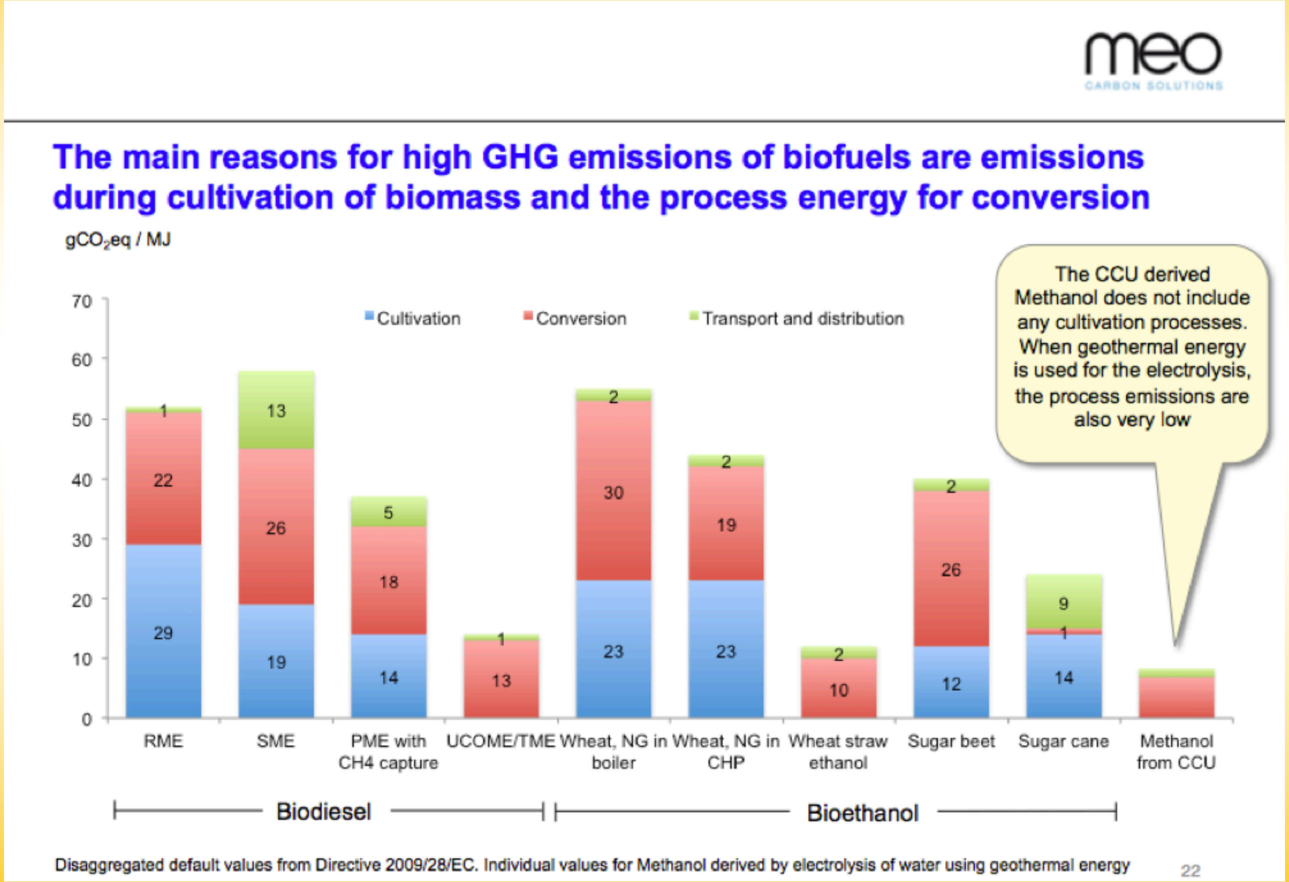
- The PtL production is only meaningful if renewable electricity is used
- If renewable electricity is used the CO_2 eq. savings compared to fossil Diesel are in between 40 to 95%
- Using waste heat of the PtL plant for the DAC is more favourable than using Natural gas → But then the plant have to be close to each other

Source: University Stuttgart 2015

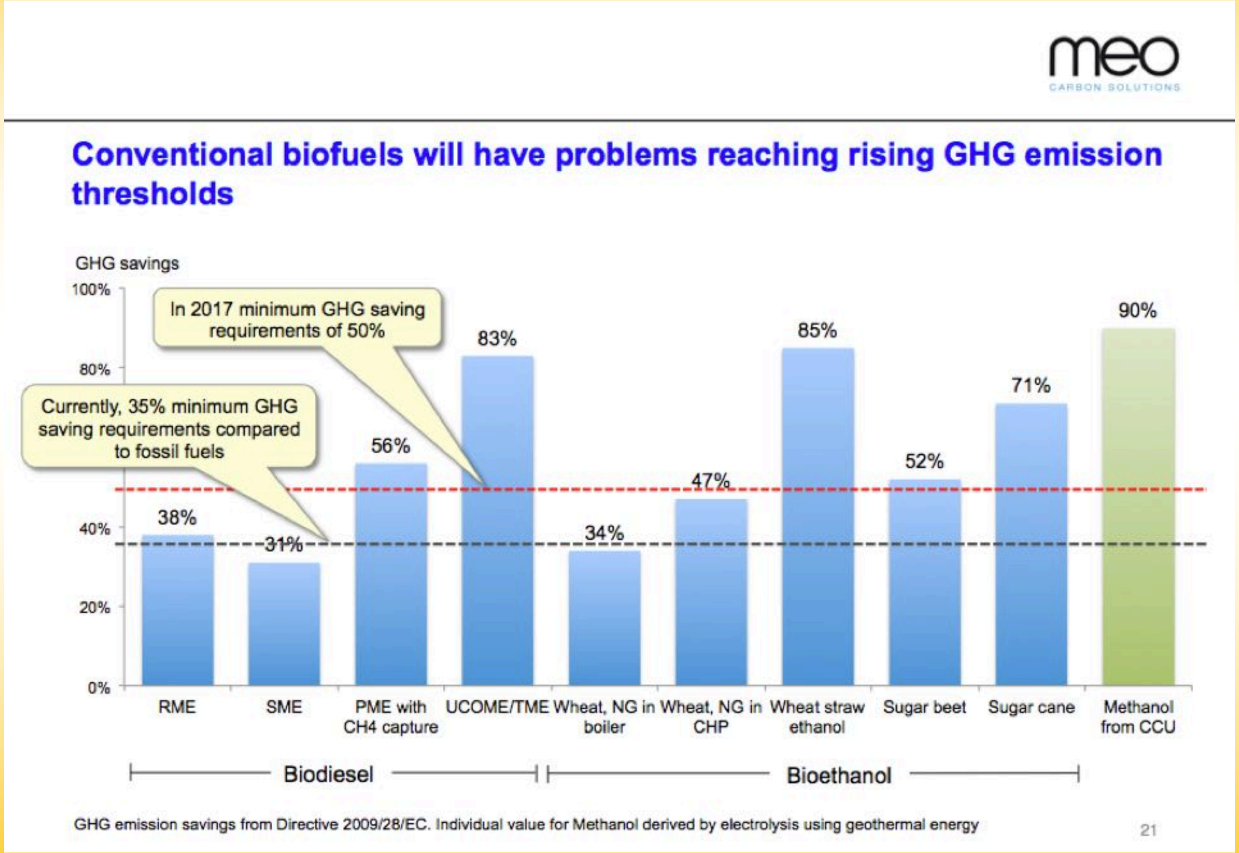
Contact

CO_2-based methanol from Iceland

GHG emissions calculation based on RED



90% GHG savings with methanol from CCU even higher than second generation biofuels



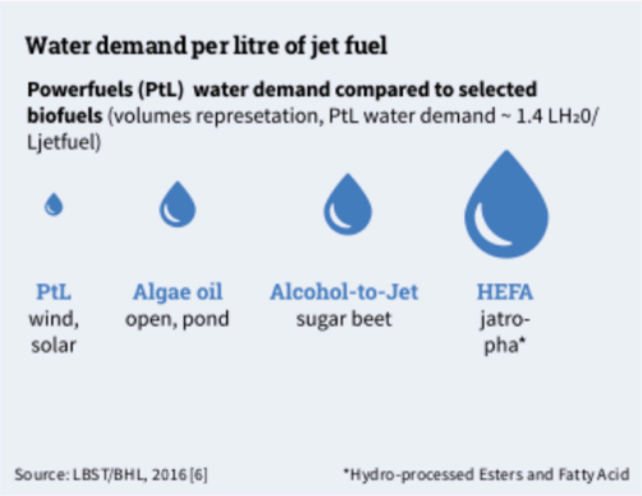
Comparison of different jet fuel feedstocks and pathways – CCU jet fuel is the best

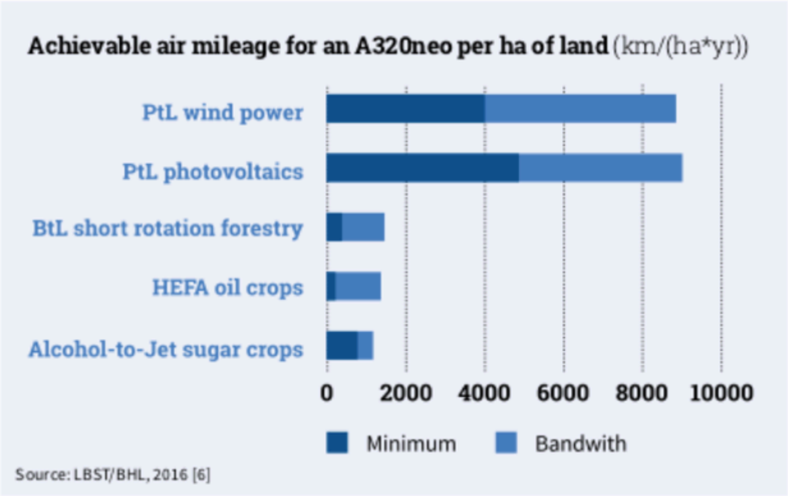
	Jet fuel yield (GJ/ha*y)	GHG emissions without LUC (g CO_2 eq/MJ fuel)	GHG emissions with dLUC (g CO_2 eq/MJ fuel)	Green + blue water demand (m^3/GJ)
Crude oil		87.5		
Natural gas		101		
Rapeseed oil (HEFA)		55	98	
Jatropha oil (HEFA)	15 - 50	39		574
Palm oil (HEFA)	162	30	40 - 700	150
Algae oil (HEFA)	156 - 402	51		14 - 53
SRC (short rotation coppice)	47 - 171	18	- 2	112
PtL (solar)	580 - 1070			
PtL (wind)	470 - 1040	1 – 28 (*)		0.04 – 0.08

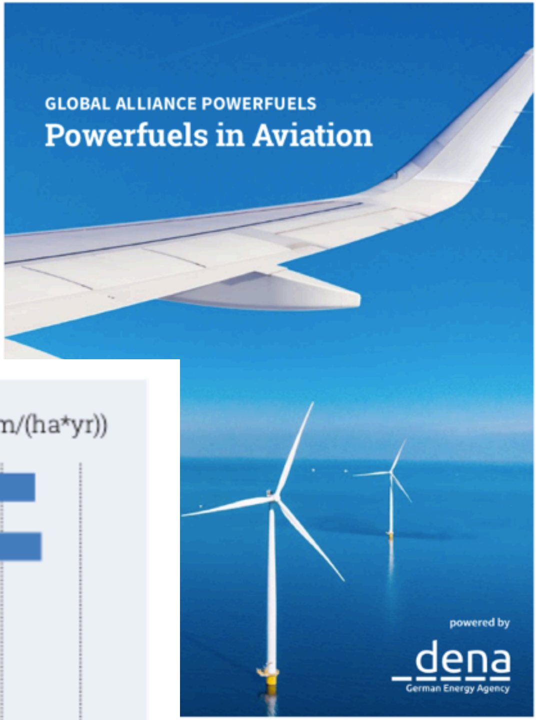
Summary, based on: Schmidt, P. et al. 2018: Power-to-Liquids as Renewable Fuel Option for Aviation: A Review. In: Chem. Ing. Tech. 2018, 90, No. 1-2, 127-140. / (*): In a today's mainly fossil energy landscape in material sourcing and construction.

Global Alliance Powerfuels

German Energy Agency (dena) on Sustainable Aviation Fuels (SAF) (Sept. 2019)



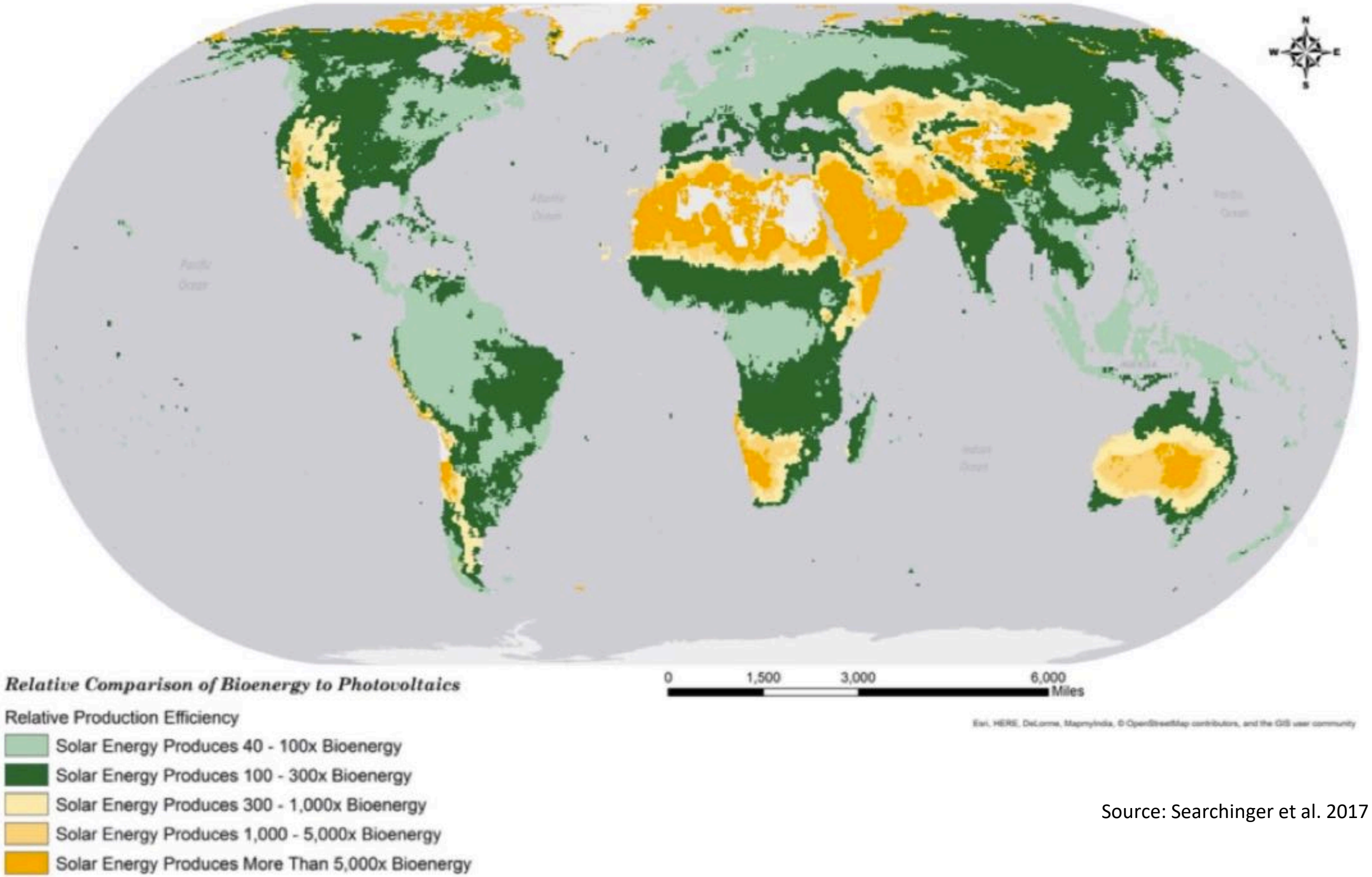




Source: dena 2019

Figure 2: Water demand per litre of jet fuel and achievable air mileage. [6]

T.D. Searchinger et al. Energy Policy 110 (2017) 434–446



Source: Searchinger et al. 2017

Fig. 1. Comparison of land use efficiency of PV today versus cellulosic ethanol tomorrow. On 73% of the world's land, the usable energy output of PV would exceed that of bioenergy by a ratio of more than 100 to 1. On the 27% of land with a ratio less than 100 to 1, the average ratio would be 85 to 1.

Solar energy in average 85 times more land efficient than bioenergy, CCU fuels (with 50% efficiency) 40 times more land efficient than bioenergy!

Can the European Union's kerosene demand be met by the amount of biomass produced in the EU?

Table 1: Different biomass sources and PtL production pathways of jet fuel and kerosene: Yields per hectare and area demand in the European Union

Production pathway	Jet fuel yield (GJ/ha*a)	Jet fuel / kerosene demand in the EU, 2018 (million GJ)	Area required for the entire coverage of the EU jet fuel / kerosene demand (million ha)	Current area cultivated in the EU (million ha)	How much of the current area is needed to fulfil the jet fuel / kerosene demand in the EU
Maize (AtJ)	56	2,895	51.7	8.3	x6.2
Sugar beet (AtJ)	149	2,895	19.4	1.7	x11.2
Rapeseed oil (HEFA)	48	2,895	60.3	6.9	x8.7
Sunflower oil (HEFA)	31	2,895	93.4	4.0	x23.2
PtL PV	580-1070	2,895	5 - 2.7	no data	no data
PtL wind	470-1040	2,895	6.2 - 2.8	no data	no data

Notes to the table:
AtJ: Alcohol-to-Jet fuel (based on bioethanol)
HEFA: Hydroprocessed Esters and Fatty Acids
PtL: Power-to-Liquid
PV: Photovoltaic

The EU's total agricultural area is 107 million ha (2017)

Crop yields based on FAOSTAT 2016, yields biomass to jet fuel / kerosene based on UBA 2016: Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel.

Source: nova-Institut 2020

Can the European Union's kerosene demand be met by the amount of biomass produced in the EU?

The high demand for aviation fuel / kerosene in the European Union can only be met to a very small extent by domestic biomass. **If this path is taken, more than 95% of the biomass must be imported.**

Covering the demand via Power-to-Liquid with the help of solar and wind energy and CO_2 is comparatively easy due to the considerably higher efficiency of the land use. It is expected that this will result in the use of a **mix of domestic renewable energies and imports from North Africa**.

It should be noted that covering only **0.2% of the Sahara's surface area with photovoltaics would be sufficient to cover the EU's entire aviation fuel / kerosene requirements**.

Economic Assessment

Costs for different SAF in comparison to conventional aviation fuels and ticket price increase by blending quotas of 2%, 10% or 50%

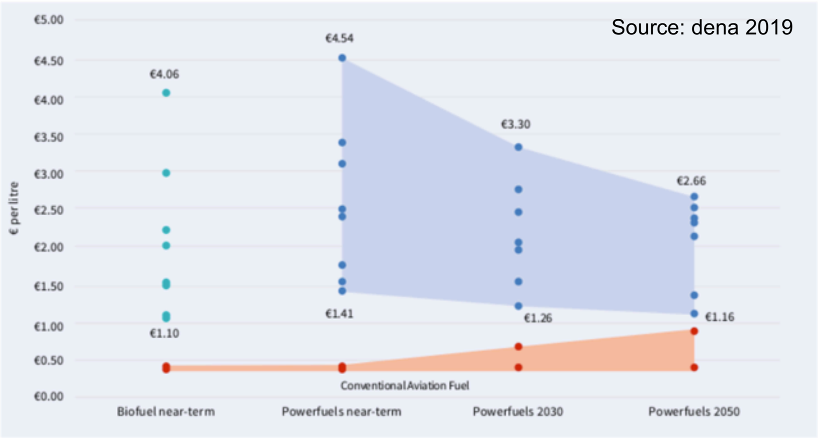


Figure 3: Cost estimates for biofuel and powerfuel SAF in the literature (€/litre) compared with Conventional Aviation Fuel (CAF).[7]

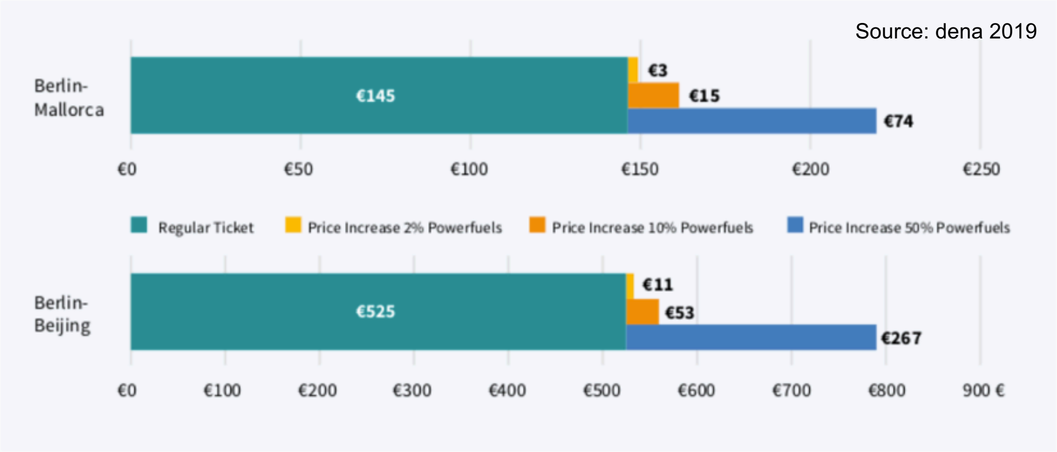


Figure 5: Ticket price increase by blending conventional aviation fuel with different proportions of powerfuels.

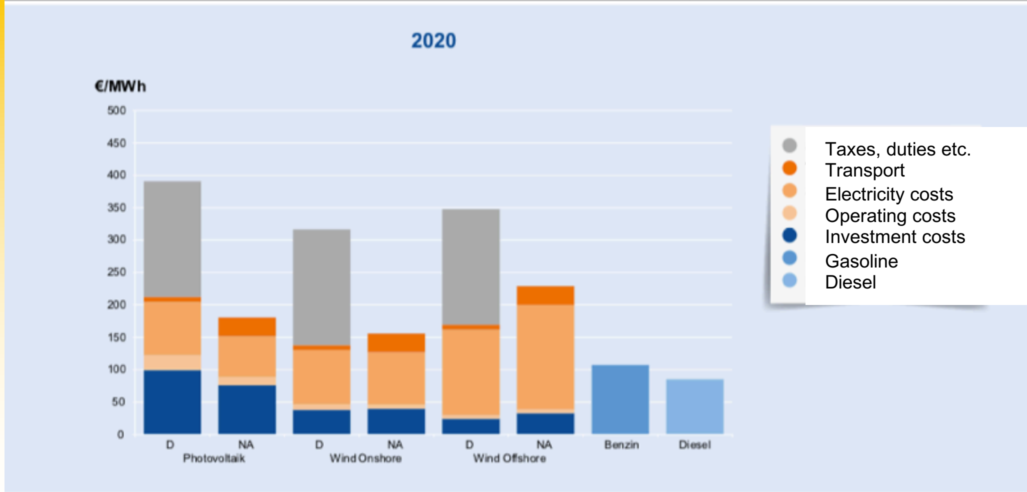


Abbildung 6: Wasserstoffgestehungskosten (2020): Quelle: enervis

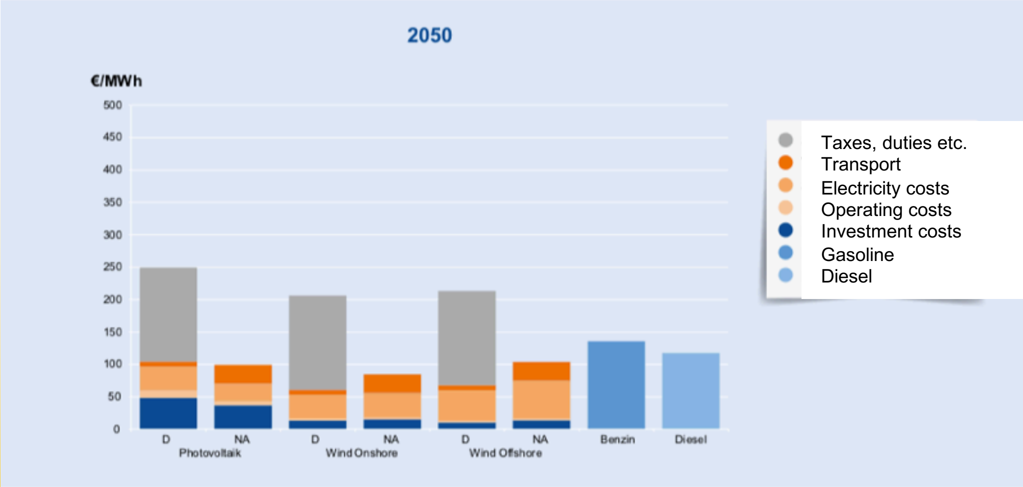


Abbildung 7: Wasserstoffgestehungskosten (2050): Quelle: enervis

Hydrogen production costs 2020 and 2050 in Germany (D) and North Africa (NA) for use in Germany

Costs: Green hydrogen as a precursor of CO_2-based kerosene can certainly be produced in Central Europe due to the transport costs from North Africa, if it is to be used in Central Europe.
Land: Rather than the price, it is a question of the space available.

In 2050 green hydrogen will be fully competitive with diesel and gasoline.

Unique win-win situation: CO_2-based Aviation Fuels

- The only realistic, viable way to completely replace fossil kerosene
- Highest GHG savings, lowest land use, lowest water consumption
- Unique win-win situation for Europe and North Africa
- Already with mandatory blending quota of 5%, very considerable effects
  - Several 100 million investment in rural areas (renewable energy) and chemical parks (hydrogen, CO_2, kerosene)
  - Creation of several ten thousands of new jobs in rural areas and the chemical industry
  - Moderate economic effects for customers: If 5% of the kerosene is three times the price, for example, fuel costs increase by only 10%. Even discount flights would become less than 10% more expensive as a result – something that is politically and publicly desired anyway.
- A mandatory kerosene blending quota would give the entire Carbon, Capture and Utilisation (CCU) sector the necessary push to replace fossil carbon quickly and on a large scale in all sectors and thus halt climate change: Because without additional carbon from the soil, climate change is stopped.

We should do everything we can to communicate this concept, find supporters and forge majorities: A binding quota for CO_2-based kerosene in Europe is the key!

Thank you for your attention!

CEO

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