TAB

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Climate neutral truck traffic due to algae-based fuels?

Source: André Künzelmann, Anne Wessner, UFZ

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Summary

- Biofuels produced from algae represent an innovative approach with regard to the renewable and climate-friendly energy supply of the truck fleet which currently is predominantly powered by diesel fuel.
- Algae have a significantly higher productivity than conventional energy crops and can help prevent land use conflicts with food production or nature conservation.
- Research on the production of algae-based fuels is being conducted worldwide. So far, however, it has not been possible to produce algae-based fuel in an energy-efficient and economically viable way on a scale that is relevant for road haulage.
- Options for improving competitiveness can be found in optimising the selection and cultivation of algae and the utilisation of algae in so-called biorefineries, where various algae-based resources and products are produced simultaneously.

What is involved

In 2016, with more than 165 million t CO_2 equivalent, transport accounted for about 16 % of total greenhouse gas emissions (GHG emissions) in Germany. More than one third of total GHG emissions in the transport sector originate from road haulage. While other sectors have achieved significant emission reductions since 1990, GHG emissions from road traffic have even risen slightly and are counteracting the German Federal Government's goal of widely achieving climate neutrality in Germany by 2050. Although the specific emissions per km driven could be reduced by means of improved engine and propulsion technology, this was more than offset by the overall increase in transport volume.

Biofuels are an important element for the reduction of GHG emissions originating from transport. In 2018, their share in the total final energy consumption of transport was approx. 5 % (fig. 1). Biofuels are obtained from renewable resources and are therefore largely GHG-neutral. Moreover, they can be used with the established propulsion technology for trucks and the existing supply infrastructure.

In recent years, however, biofuels have been criticised for triggering changes and conflicts of land use due to the cultivation of energy crops on agricultural land and for provoking an increase of food prices. For this reason, biofuels based on algae biomass are propagated. The algae can be cultivated on sites that are neither suitable for agricultural production nor particularly worth to be protected for nature conservation reasons. In addition, algae production can achieve productivity levels per unit area that are higher by a factor of around 7 to 30 compared to biomass based on terrestrial plants.

How is biomass obtained from algae?

The general term algae refers to a large number of organisms living in water and performing photosynthesis. Algae are basically divided into macro-algae and micro-algae. Macro-algae have easily recognisable stems and leaves and are often rooted. Micro-algae are much smaller, consist of a single or just a few cells and are diverse and adaptable species. Their size is in the nanometer to millimeter range. Conservative estimates assume that there are more than 70,000 micro-algae species.

Due to the enormous diversity of algae, considerable research efforts have been made to identify algae species particularly suited for fuel production and their optimal cultivation conditions. In principle, biomass from both macro-algae and micro-algae can be used as a resource for fuel production. However, the cultivation of macro-algae is only possible in natural waters involving the fact that yield and quality of the algae biomass are subject to strong fluctuations. In

Client
Committee on Education, Research and Technology Assessment
+49 30 227-32861
bildungundforschung@bundestag.de

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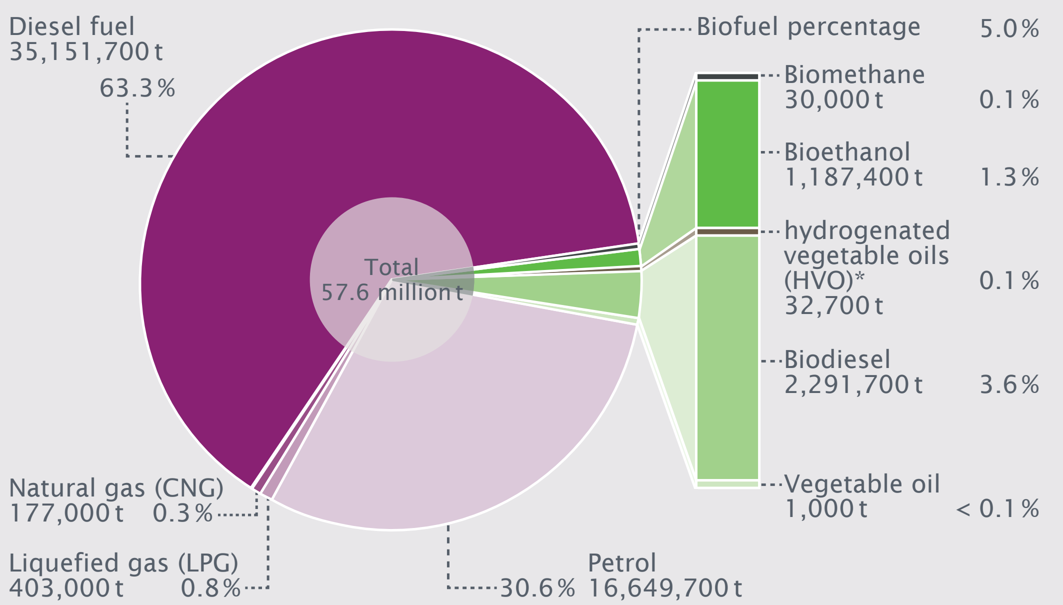
contrast, the cultivation of micro-algae is characterised by higher growth rates due to the fact that nutrients are used more efficiently and production can be better controlled on a technical level. This also enables a targeted stimulation of the formation of algae constituents that are particularly relevant for fuel production.

Micro-algae are cultivated in open or closed systems. In open production systems, the culture medium consisting of water and nutrients is circulated in shallow basins to ensure that the algae are uniformly exposed to the sunlight. Advantages of this production method are the comparatively simple technology of the systems as well as the relatively low energy consumption. However, seasonal fluctuations of the heat and light conditions as well as the evaporation of the culture medium have a negative effect. Another challenge is the risk of contamination by inputs of exhaust gases or by micro-organisms, insects or birds. Closed production systems consist either of long transparent tubes or flat, vertically erected plates through which the nutrient medium is pumped permanently. Thus, fluctuations of temperature and radiation can be compensated for. Compared to open systems, the controlled conditions in closed systems allow a higher productivity and the algae can be produced with high purity and the desired properties. Disadvantages of closed systems are the more complex and cost-intensive technology as well as the higher energy input.

Fig. 1 Fuel consumption in Germany in 2018



* Estimate

Percentages based on energy content

Source: FNR 2019 according to BAFA, Destatis, DVFG, BDEW, BLE (2019)

How can fuel be produced from algae?

Algae biomass can be processed into biofuel in various ways. The most thoroughly investigated fuel path is the use of the oils or lipids contained in algae, which can be processed into fuel in conventional refineries. In order to obtain the algae oils, the algae biomass must first be collected and dried. Various processes have been developed for harvesting, drying and oil extraction which are technically demanding and very energy-intensive. This means that the energy required for fuel production exceeds the energy content of the fuel obtained. In some cases, it is necessary to use environmentally hazardous flocculants and solvents.

The oils obtained from the algae can be converted into biofuels by a number of different processes. With regard to a decarbonisation of long-distance road haulage, those processes that produce biofuels that could be blended with fossil diesel or completely replace it are of particular relevance. Thus, it is possible to convert algae oils into fatty acid methyl ester (FAME). Furthermore, diesel substitutes can be produced by hydrogenation of oils (hydrotreated vegetable oils [HVO] or hydrotreated esters and fatty acids [HEFA]). Both processes are already established for the use of other types of biomass. In 2015, for example, approx. 25 million t of FAME diesel and approx. 3 million t of HEFA fuels were produced worldwide. However, there is currently no facility for commercial production using algae oils.

In order to avoid the technically and energetically complex process of extracting algae oils, more and more research is being carried out with regard to fuel paths that use the entire algae. Thus, for example, it is being investigated how synthetic fuels can be produced from algae biomass – a process that has already been well researched for other renewable resources such as straw and wood. Even greater hopes are placed in the fuel path of hydrothermal liquefaction which does not require any drying of the algae biomass. Although both methods are considered to have a great potential, there is still considerable need for development. After all, instead of diesel substitutes, kerosene or gaseous fuels can potentially also be obtained from algae biomass.

Costs of producing algae fuels

Due to the early stage of technological development, the quantities of algae-based biofuels that can be produced and the production costs involved can only be estimated with great uncertainty. Under the climatic conditions in Germany, an average annual yield of algae biomass of approx. 30 to 50 t/ha in open production systems and 30 to 100 t/ha in closed production systems can be assumed. In addition to the annual yield, another decisive factor for the yield of biofuels is the oil content of the algae, which can vary substantially depending on the type of algae and the supply of nutrients in the growth medium.

For comparative calculations, average oil contents of 25 to 30 % of the algae biomass produced are often used. According to this, about 7.5 to max. 30 t/ha of algae oils could be produced in Germany. A comparison with rapeseed – which is by far the most important oil plant in Germany – reveals the fundamental potential of algae for fuel production: With an average annual yield of 3.5 t/ha and a standard oil content of 40 %, the rapeseed oil yield is only 1.2 t/ha.

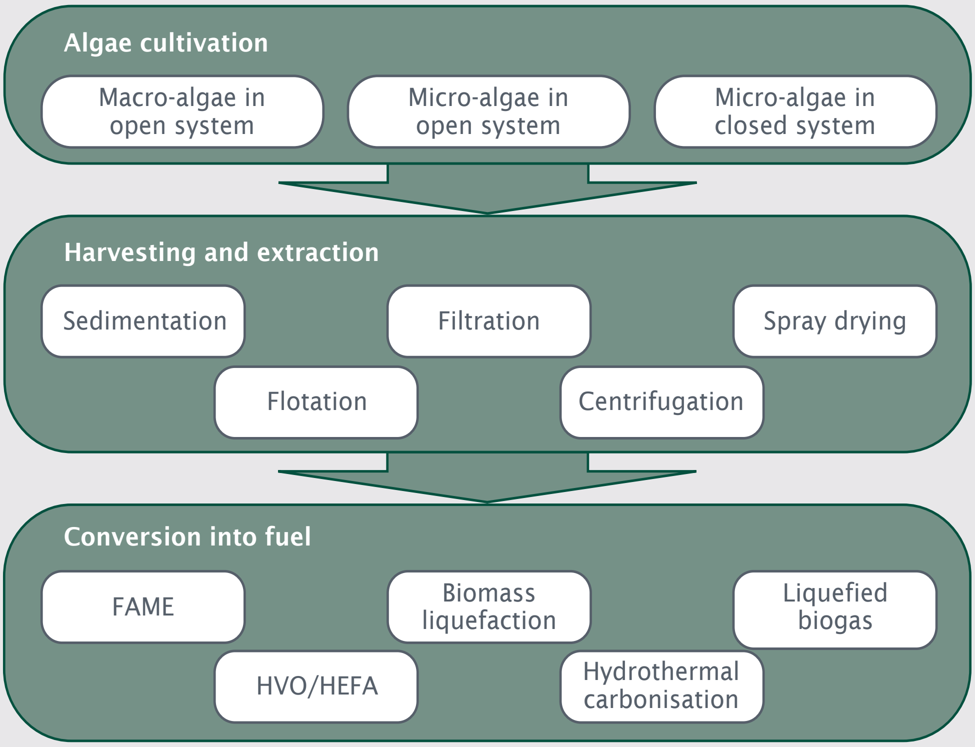
However, a large obstacle regarding the competitiveness of algae-based biofuels are the production costs for algae biomass – which are estimated to be 500 to 20,000 EUR/t for open systems and 500 to even 100,000 EUR/t for closed systems. In comparison, the producer price levels for rapeseed (approx. 330 EUR/t) and wheat (approx. 170 EUR/t) are significantly lower. Generally, however, the costs for further processing algae oils into fuels are similar to those of other biofuels based on vegetable oils.

The potential of algae fuels: high in theory – low in practice

One the one hand, considering the potential of algae-based biofuels with regard to a decarbonisation of road haulage, the theoretical advantages of this technology become evident. The higher productivity per unit area compared to the production of plant-based resources as well as the possibility of producing on sites that do not compete with food production or nature conservation help mitigate undesirable side effects of biofuels. Unlike fuels produced from fossil resources, a favourable GHG balance can also be expected.

On the other hand, the scientific state of knowledge shows that algae-based biofuels cannot make a contribution to climate-neutral transport in the short and medium term in view of the production options currently assumed to be plausible. At present, for example, more energy has to be invested in the production of algae oils for fuel production than is ultimately produced in the form of the actual fuel. Moreover, the still early phase of technology development as well as the high production costs of algae biomass result in industrial production structures for algae fuels being unlikely to be established in the medium term. In addition, for Germany, the potential supply of land for algae production and the productivity of algae under the prevailing climatic conditions are limited.

Fig. 2 Steps in the production of algae fuels



In summary, it can be stated that a noticeable contribution to improving the GHG balance of road haulage by 2050 cannot be expected from algae-based biofuels. This would require scientific and technological breakthroughs as well as process innovations that are not yet foreseeable. Electricity-based propulsion concepts seem unavoidable for achieving GHG-neutral transport.

In this context, the use of synthetic fuels and limited quantities of sustainably produced biofuels would tend to be restricted to areas where direct electrification is technically or economically not feasible (e. g. air and sea transport).

Approaches to realising the potentials

An examination of the current state of knowledge revealed that if algae-based fuels are to be produced on an industrial scale and in a way that makes sense from a sustainability perspective, significant progress is needed – particularly with regard to their energy balance. For this, a more targeted selection of algae species as well as process innovations with regard to the extraction of algae oils and their further processing into fuels are possible approaches. A comparison with other fuels shows that the main challenges consist in the production of algae biomass. From a technical point of view, however, there is still a need for specific development in fuel production, but the real bottleneck is the mass production of algae required for this purpose.

In order to approach the theoretical potentials of algae technology in practice in an appropriate way, intensive research is currently being made to utilise algae biomass as comprehensively as possible in biorefineries. For this, the focus is on producing highly priced algae-based products with a high marketing potential (e. g. food supplements, cosmetics, chemical compounds). This approach – in which fuel production is only a secondary aspect – could help reduce the cost of producing algae biomass to a marketable level.

As a second possibility, the use of waste water as a nutrient medium for algae cultivation is an interesting approach. The resulting synergies between nutrient supply and waste water treatment could be an option to reduce the costs of algae fuel production in the long term. However, there are still numerous research questions resulting from the complex and multi-link process chain that ranges from the cultivation of algae biomass to the production of algae-based products. To answer these questions, the funding of pilot plants seems to be appropriate in order to support the available model-theoretic considerations in scientific literature with real operating data.

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Das Potenzial algenbasierter Rohstoffe für den Lkw-Verkehr

Christoph Schröter-Schlaack and Christoph Aicher
assisted by Reinhard Grünwald, Christoph Revermann and Johannes Schiller

Website of the project
www.tab-beim-bundestag.de/en/research/u20600.html

Project Manager and contact
Dr. Reinhard Grünwald
+49 30 28491-107
gruenwald@tab-beim-bundestag.de

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