Fraunhofer
UMSICHT

FRAUNHOFER INSTITUTE FOR ENVIRONMENTAL, SAFETY, AND ENERGY TECHNOLOGY UMSICHT

FRAUNHOFER UMSICHT TAKES A STAND

Topic: Fuels of the future

A POSITION PAPER OF THE SERIES "UMSICHT TAKES A STAND"
OBERHAUSEN | MAY 2020

FRAUNHOFER UMSICHT TAKES A STAND
Topic: Fuels of the future

Within the series of position papers "Fraunhofer UMSICHT takes a stand" we cover issues which currently attract the attention of society, science and economy. In addition to our research activities, we would like to take a stand and make a contribution towards greater objectivity in emotional debates. At the same time we would like to show whether and how we can help to solve societal challenges.

Our statements are developed within the staff of Fraunhofer UMSICHT. Each position paper is the result of an opinion-forming process throughout the institute; in this case driven by the Bio-Based Plastics department, which was supported by the Sustainability Group. In controversial issues, the staff of our institute often displays the diversity of opinions within the society. We openly present the variety of opinions in our position papers if we cannot come to one single position concerning the subject in question.

Please contact us:

For questions regarding the position paper about fuels of the future:

Director Institute Branch Sulzbach-Rosenberg
Prof. Dr. Andreas Hornung
+49 9661 8155 502
andreas.hornung@umsicht.fraunhofer.de

For questions regarding our position papers in general:

Sustainability and Participation
Dr. Markus Hiebel
+49 208 8598 1181
markus.hiebel@umsicht.fraunhofer.de

Head of Department
Biorefinery and Biofuels
Dr.-Ing. Andreas Menne
+49 208 8598 1172
andreas.menne@umsicht.fraunhofer.de

Fraunhofer Institute for Environmental,
Safety, and Energy Technology UMSICHT
Osterfelder Strasse
346047 Oberhausen
Germany

Please quote the position paper as follows:

Fuels of the future – Fraunhofer UMSICHT takes a stand, UMSICHT Position Papers, Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT (ed.), Oberhausen, May 2020

Picture credits front page:
© shutterstock

Status of the document: May 2020

1 Background

Germany has set itself the goal of becoming largely greenhouse gas neutral by the year 2050. In order to achieve this goal, greenhouse gas emissions are to be reduced by at least 55 percent by 2030 compared to 1990 levels. The climate protection plan of the German government therefore also sets a target of 40 to 42 percent greenhouse gas savings by 2030 for the transport sector [Bund 2016]. But how can this goal be achieved? Are technical innovations for motor vehicles a panacea, or will far-reaching changes in mobility behavior also be required, which will also affect the way we work and live in the future?

Technical solutions to reduce greenhouse gas emissions in the transport sector are usually based on replacing fossil fuels with electricity generated from sun, wind or biomass. The direct way to integrate solar and wind energy into the transport sector is to equip motor vehicles with electrically powered engines that are supplied with electricity from a rechargeable battery. Although this automotive technology – known as e-mobility – still faces challenges due to the large amount of resources used in the manufacture of batteries, problems in building infrastructure and reduced range, electrically powered vehicles make it possible to develop a largely CO_2-free energy source for the transport sector[1]. The direct use of electricity with electric drives has the lowest conversion losses compared to most other options. The question therefore arises as to whether in the future there will only be means of transport with battery electric drive and/or fuel cells or whether combustion engines with the associated fuels will still be needed.

[1] The prerequisite for this is that the electricity must be from non-fossil sources.

2 Positions of Fraunhofer UMSICHT

1. **Will fuels still be needed in the future?**
   Even if passenger car transport in Germany can be largely converted to electric motors, there are still large areas of the transport sector in which a purely battery electric drive is difficult, if not impossible. These areas include air travel, shipping, agricultural transport and possibly also construction machinery and heavy goods transport.[2]

   → *Fuels with high energy density will continue to be needed in the future.*

2. **Which raw materials will have to be used to produce fuels in the future?**
   In order to achieve greenhouse gas neutrality without compensation measures, the required fuels must have a regenerative basis. Other fossil fuels such as coal only offer advantages over oil and gas in terms of their national and long-term availability. In macroeconomic and climate protection terms, the use of coal as a raw material for fuels is disadvantageous.

   Conventional fuels produced from fossil raw materials can in principle be replaced by hydrogen. The advantage of using hydrogen directly as an energy carrier is that energy is released when it is reacted with oxygen, resulting in water as a reaction product. Compared to fuels that can be produced from CO_2 using hydrogen – such as methanol – the direct use of hydrogen is more energy-efficient, since additional conversion steps are associated with energy losses. At the same time, hydrogen is "carbon-free" and therefore does not lead to CO_2 emissions. With the help of fuel cell technology, hydrogen can be used directly to drive electric motor vehicles.

   It is also possible to produce carbon-containing fuels, which are comparable in composition to today's fuels, on a regenerative basis. Under certain conditions, which are based on the principle of sustainability, biomass or residues from biomass can also be used as raw materials for fuels. The production of fuels from biomass can be carried out using fermentation, gasification and pyrolysis processes. In pyrolysis processes, an energy-rich liquid is obtained from biomass by heating it under the exclusion of most oxygen. This liquid can then be processed into fuels. Fermentation processes initially supply a so-called "synthesis gas" as a product, which essentially consists of CO, CO_2 and hydrogen, which can be converted into various fuels with the aid of catalysts in known and proven process routes. Since synthesis gas can also be produced from CO_2 and hydrogen, CO_2 is in principle also suitable as a raw material for fuels. Another possibility is the biotechnological conversion of synthesis gas into hydrocarbons using enzymes or microorganisms. Technical processes for the production of fuels from biomass or CO_2 are relatively well developed. There are often fewer - technical than economic, regulatory, logistical and ecological obstacles to their implementation.[3]

   → *In the future, hydrogen can be used as a fuel or fuels can be produced from CO_2 and hydrogen as well as from biomass.*

[2] Further information on future fuel requirements can be found in the white paper of DECHEMA [Wagemann-2017] and a study by Prognos AG, Fraunhofer UMSICHT and the German Biomass Centre.

[3] The use of biomass and CO_2 as raw materials for fuels and chemicals is discussed in a Fraunhofer UMSICHT issue [Marzi-2017]. A study by DECHEMA [Bazanella-2017] provides an overview of the state of development of the required technical processes.

3. Is sufficient biomass available for fuel production?

Biomass as a resource is limited nationally and globally and often only available in large quantities in selected countries or parts of countries. When cultivating biomass, priority must be given to food supply and cultivation must be based on criteria of sustainability, which also take into account aspects of species protection and social factors.[4]

→ *Preference should be given to using residues of biological origin as raw materials for fuels. The scale and type of cultivation of energy crops must be socially acceptable and must not endanger food supplies or existing ecosystems.*

4. Is sufficient CO_2 available for fuel production?

After power plants have been shut down, the main sources of CO_2 are still available in the long term, for example in metallurgical[5] and cement works and thermal waste treatment. Whether it will be possible in the future to extract CO_2 from the air on such a scale that sufficient quantities of fuels can be produced from it, taking into account sustainability criteria, is still a controversial question. The concentration of CO_2 in the waste gases of the above-mentioned processes is orders of magnitude higher than in air.

→ *It can be assumed that, initially, unavoidable waste gases from industrial processes will serve as sources of CO_2.*

5. Where does the renewable energy needed to produce future fuels come from?

The production of future fuels requires hydrogen, which is either used directly as a fuel or is needed as a reaction partner for CO_2. In the future, hydrogen will probably be produced by electrolysis of water, which will require considerable amounts of renewable electricity. An even greater amount of electricity is required when CO_2 is converted into fuels. The available wind and solar energy potential in Germany is limited and will continue to be used primarily for electrical energy and, in the future, for heating. Viewed globally, there are locations that have higher renewable energy potentials than Germany.[6]

→ *It must be prioritized for which purposes the renewable energy potential that can be tapped in Germany is to be used. The supply of fuels requires international cooperation that includes regions with high renewable energy potentials. The aim of these cooperations must be to replace existing oil and gas imports with imports of renewable energy sources. It is important to structure these international cooperation projects in such a way that sustainable development can also take place in the regions that export the energy sources. The systemic linking of electricity, CO_2, hydrogen, intermediate products and fuels represents a political, economic, social and logistical challenge.*

6. Is (one) technology sufficient to meet the fuel demand?

Both biomass potentials and the potential of renewable electricity are limited. Concepts that rely exclusively on technology or only on one technology will therefore probably not be sufficient to ensure the desired mobility of people and goods and service-related transport.

→ *Concepts that rely on biomass or CO_2 as a raw material for carbonaceous fuels complement each other. Future regenerative fuels will have to rely on both sources of raw materials. In addition, mobility concepts need to be rethought, traffic volumes reduced and the transformation of the energy system considered as an interdisciplinary task.*

[4] Information on available biomass potentials can be found in a study by the German Biomass Centre [Knebel-2014].

[5] If it is possible to use hydrogen instead of carbon to convert iron ore into pig iron in iron and steel works, the amount of CO_2 that can be supplied from steelworks will be reduced.

[6] The use of CO_2 as a raw material and the quantities of renewable energy required for this purpose are discussed in a Fraunhofer UMSICHT issue [Marzi-2017]. A study by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e. V.) looks at the renewable energy potentials that can be tapped in Germany [Kreyenberg-2015]. A study by the World Energy Council deals with the potential of renewable energies for fuels and chemicals [Perner-2018].

7. Which fuels are needed?

If hydrogen is to play an important role in the mobility sector in the future, this will require new energy conversion technologies for the propulsion of motor vehicles and a comprehensive hydrogen infrastructure that is also suitable for heavy-duty traffic. It may be necessary here to define a balanced mix of hydrogen infrastructure and infrastructure for electric mobility. In order to ensure international transport, appropriate hubs should be provided as interfaces and an international, at least EU-wide strategy should be developed.

For air transport in particular, fuels must have the highest possible energy density. The energy density indicates the amount of energy that is bound in a certain volume or in a certain mass of the fuel. A high energy density therefore enables a long range or a reduction in the amount of fuel that has to be carried in the tank. Hydrocarbons have a particularly high energy density[7]. In principle, they can be produced with so-called "Fischer-Tropsch processes" from synthesis gases, which either originate from biomass gasification or are produced from CO_2 and hydrogen. Pyrolysis processes, the hydrogenation of vegetable oils or the use of alcohols also make it possible to produce standard fuels. These can then be used in combustion engines alone or mixed, and possibly also in fuel cells.

Alcohols can also play a key role in the production of fuels from biomass or CO_2. Alcohols can be processed into hydrocarbons and ethanol is already being added to petrol as E10. Whether methanol is to be used as a fuel or as a fuel additive varies internationally. However, methanol can be produced directly from CO_2 and hydrogen and is the starting product for fuels that are being discussed as diesel substitutes or additives. These include oxymethylene ether (OME) and dimethyl ether (DME), both of which have the advantage of producing few nitrogen oxides and little particulate matter during combustion. Besides fuels, methanol can also be used as a starting material for important basic chemicals. Examples of such basic chemicals are ethene and propene, which are currently obtained either from crude oil or shale gas.[8]

→ *In the future, hydrocarbon mixtures, and possibly also ethanol, methanol and methanol compounds, will play an important role as fuels or fuel additives. The production plants will be flexible with regard to their target markets and will, for example, produce methanol for the fuel and chemicals market as required.*

3 Necessary steps from the perspective of Fraunhofer UMSICHT

1. Since not all transport sectors can be developed using battery-powered electricity, the development of hydrogen technologies and technologies for renewable fuels must be promoted in addition to e-mobility.
2. A key role, not only for the production of fuels, is played by the available energy that is free of greenhouse gases. The expansion of renewable energies must therefore be pushed forward as far as possible. Battery electric drives, hydrogen-based fuel cell applications and renewable fuels can only make a significant contribution to limiting climate change if sufficient quantities of renewable energies are available.

[7] Compared to other fuels, hydrogen has the highest energy density in terms of mass, but only an extremely low energy density in terms of volume. To reduce storage volumes, hydrogen must therefore be stored under high pressure.

[8] DECHEMA's white paper [Wagemann-2017] and a study by Prognos AG, Fraunhofer UMSICHT and the German Biomass Centre [Hobohm-2018] discuss which substances can be used as future fuels.

3. In order to secure Germany as an industrial location, fair and long-term cooperation with regions and countries that have great potential for renewable energies must be developed. In order to use the renewable energy potentials available in Germany, the most important applications must be prioritized. An efficient infrastructure for electricity and hydrogen must be provided.
4. Since it is still unclear in what proportions biomass and CO_2 will be used to produce fuels in the future and what processes will be used to do so, processes must be developed and demonstrated in parallel. Which processes will be used depends on the amount and type of fuel required, but also on the available biomass and usable CO_2 sources.
5. If today's competitive conditions continue, established processes using fossil raw materials will continue to be more economical than new processes using CO_2 and/or biomass as raw materials. In order for the new processes to become economically competitive, regenerative electricity must be cheap and CO_2 emissions must be priced sufficiently high internationally.
6. A change in transport policy requires technological innovations for battery electric drives, hydrogen-powered fuel cells and regenerative fuels. However, these innovations will not suffice for an ecologically, economically and socially successful adaptation of transport policy if interdisciplinary approaches are not simultaneously used to reduce the volume of traffic and adapt traffic concepts.
7. The infrastructure and production of fuels and their use require a long-term reliable regulatory basis.