Commercializing Conventional and Advanced Transport Biofuels from Biomass and Other Renewable Feedstocks

Task 39 IEA Bioenergy

Inside this Issue

From the Task

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Since publishing our last Newsletter in December 2019, IEA Bioenergy Task 39 has continued its work to advance the commercialization of sustainable, lower carbon intensive transport biofuels to decarbonize the multi-faceted transport sector.

Virtual Business Meeting in April 2020

The first business meeting of Task 39 in 2020 was held on 2 April, virtually using Zoom, due to the coronavirus pandemic, which resulted in severe restrictions on travel and physical meetings, postponement of the BBEST 2020 and Biofuture Summitt II conference, and cancellation of IEA Bioenergy meetings in São Paulo, Brazil. These included the Task 39 business meeting on 2 April and the Task 39-Task 45 Joint Workshop on "Sustainability of Biofuels" on 3 April 2020.

The original meeting agenda, prepared for the planned but cancelled in-person business meeting in São Paulo on 2 April, was condensed into a 3-hour virtual meeting. Progress updates on Task 39's proposed projects for the current triennium were provided by member(s) of each prospective project team and discussed with the larger group. The list of Task 39's projects for 2019-2021 triennium includes:

Continuation of Drop-in Biofuels Project

Task 39 originally published the report, Potential and Challenges of Drop-in Biofuels, in 2014. This report was updated in 2019 (Drop-in Biofuels - The key role that co-processing will play in its production). The continuation of this work (over 2019-2021) will be divided into five parts: 1) an update of the more technical aspects of the previous reports; 2) a new section expanding on biojet and marine biofuels; 3) an update of co-processing pathways and insertion points at petroleum refineries and estimating the carbon intensity of drop-in biofuels produced through co-processing; 4) a section on the policies that will be required to promote the production and consumption of drop-in biofuels; and 5) the

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We welcome your feedback. Please direct your comments to Mahmood Ebadian

life cycle analysis (LCA) of the production and use of drop-in biofuels. Specific policies will likely have to be developed and implemented to help establish drop-in biofuels, partly because some of these sectors – especially aviation and marine – are highly international and each has its own unique characteristics and challenges.

Biojet fuels - technologies and status of commercialization

This project reviews technology platforms for producing sustainable aviation fuel (SAF)/biojet, approved and ongoing ASTM certifications, current global production of biojet globally and future projected production capacity, biojet techno-economic analysis (TEA) studies and current and emerging biojet policies. This report will expand on the technology brief that the Task 39 project team prepared for IRENA in 2017.

Implementation Agendas - compare and contrast policies used to develop biofuels

The Task's periodically issued Implementation Agendas report summarises and evaluates the effectiveness of policies being used within Task 39 member countries to encourage the production and use of biofuels. It also summarises the market penetration of biofuels in member countries as well as other key countries such as China and India. So far, the Task has published five updates of this report (in 2007, 2009, 2014, 2017 and 2018-2019). The last report update was published in February 2019 and is available on the Task 39 website.

Biofuels demonstration plants database

The Task 39 pilot and demonstration plants database is an on-going activity, updated at least annually as new information becomes available through conference, presentations, news articles and Task 39 member updates. This database, which provides information and locations of advanced biofuels production facilities in Task 39 member countries and the rest of the world, can be accessed at: https://demoplants.bioenergy2020.eu/

Assess successes and lessons learned for conventional/advanced biofuels deployment

This proposed IEA Bioenergy InterTask project will document learnings from past boom-and-bust cycles of biofuel technologies development, demonstration, deployment and replication in different countries, with emphasis on major biofuels producing member countries USA, Sweden, Germany and Brazil. It aims to identify the best policy framework conditions and measures for stimulating increased future markets for production and use of sustainable transport biofuels. The proposed IEA Bioenergy project team includes members of Task 39, Task 40 and Task 45. The primary research question to be addressed is: "What is required to re-stimulate vigorous biofuels development and scale up?"

Review existing and proposed certifications for oleochemical and lignocellulosic-based biofuels supply chains; identify certification scheme improvement opportunities

The overall sustainability assessment of a biofuel is greatly impacted by the source of the biomass feedstock used to produce the biofuel. This project evaluates the existing and emerging certifications schemes for both oleochemical and lignocellulosic supply chains, from feedstock production through delivery of final products (e.g., biojet and renewable diesel) to end users. Results of this project will inform recommendations for improved sustainability certification schemes and appropriate metrics for their use. This project will also examine certification schemes for E-fuels.

Update on biofuels in marine shipping report

This project extends Task 39's "Biofuels in Marine Shipping" reporting project that published its first report in 2017. Updates to the original report will include: 1) improvements in battery technology for short distance marine transport/commuting and in harbor navigation; 2) power-to-X marine fuel options; 3) supply and sustainability of feedstocks for marine biofuel production; 4) TEA of the various marine biofuels pathways; and 5) the need for support actions, improved specifications, rules, and policies. A main objective of this update report is to identify the requirements and potential bottlenecks for commercial development and deployment of marine biofuels markets, including production capacity, fuel distribution, regulations and fuel specifications. Global initiatives supporting accelerated marine biofuel development and deployment also will be highlighted.

Analyze status of biofuels production and use in non-IEA countries/emerging economies

This project evaluates the status and potential for biofuels production in emerging economies, specifically for developing countries with large populations and high energy demand. The assessmet methodology takes sustainability concepts into account and focuses on several key performance indicators by combining TEA and LCA with Exergy analysis. The focus is on nine developing countries with substantial potential to produce biofuels, namely Colombia, Nigeria, Brazil, India, Argentina, Russia, Mexico, China and South Africa.

Conduct feedstock-to-biofuel supply chain analyses to identify potential for CAPEX and OPEX cost reduction opportunities

This project builds on two recent reports by the European Commission (EC) and IEA Bioenergy, the EC's "Cost of Advanced Biofuels" and IEA Bioenergy's "Potential for Cost Reduction for Advanced Biofuels" reports. The project focus is on existing and emerging technologies for producing sustainable, low carbon-intensive biofuels to decarbonize long-distance transport sectors, particularly marine and aviation. The costs of most advanced biofuels options are currently much higher than those of conventional biofuels and their fossil fuel competitors. There is significant potential for reducing cost through increased production allowing greater economies of scale and logistics efficiencies, in combination with the significant "learning effect" that occurs developing technologies. A supply chain approach will identify potential opportunities across feedstocks-to-biofuels supply chains for both capital (CAPEX) and operating (OPEX) costs reduction in producing advanced biofuels. In addition to identifying areas within biofuels supply chains where costs can be reduced, it will highlight opportunities for better integrating biofuels production with existing infrastructure such as petroleum refineries via approaches like co-processing to reduce the CAPEX and OPEX of advanced biofuels production.

Sustainability assessment of biofuels pathways; identify key metrics beyond GHG reduction

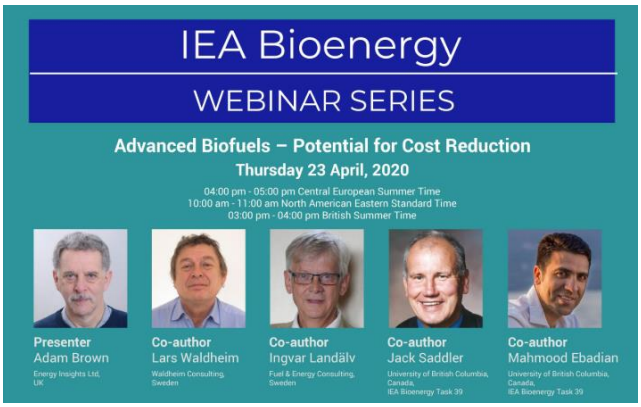
Task 39 will continue to use LCA to investigate the life cycle and sustainability attributes of different biofuel production pathways. As sustainability and carbon intensity metrics are playing an ever more crucial role in policies for biofuels development and use, sustainability assessment remains a high profile activity for the Task. The next steps regarding Task 39's LCA activities include: 1) developing complete high-quality regional data sets for LCA models and making these data sets available to model developers/users to incorporate into their assessments; 2) continuing LCA of co-processing; and 3) assessing land use change impacts. In addition, Task 39's LCA expert team plans to publish a paper intended for policy makers that will summarise and discuss the factors having the biggest impact on LCA results, including allocation issues, N_2O emissions variability, and possible soil carbon changes.

Techno-economic analysis (TEA) of advanced biofuels (including feedstocks and technology pathways)

In addition to sustainability assessment, techno-economic analysis (TEA) provides another integral tool for assessing commercializability of conventional and advanced liquid biofuels. This project will conduct TEAs on leading feedstocks x technology pathway options for producing advanced biofuels, in particular drop-in and algal-derived biofuels, to assess their economic viability and provide direction to research, development, investment and policy making. In addition, it will assess the potential to reduce the cost advanced biofuel production by "piggy-backing" their production with production of conventional biofuels .

Recent publications progress and information dissemination activities (January 2020-April 2020)

- Task 39 contributed sections to two IEA Bioenergy InterTask project reports:
  1) *Advanced Biofuels - Potential for Cost Reduction*. This project is now completed and the full report is available on Task 39's website (click here). For this report, Task 39's management team (Drs. McMillan, Saddler and Ebadian) distributed the project questionnaire to 25 advanced biofuels companies in North America and then collected and compiled cost data from 10 responding companies, contributing a section summarising this information. Task 39 also prepared two other sections, one on feedstock costs and availability in North America and the other on the role of biofuels policy in the potential cost reduction of advanced biofuels. Members of the project team presented the main findings and results in an IEA Bioenergy Webinar held on 23 April, 2020.



  2) *The Contribution of Advanced Renewable Transport Fuels to Decarbonizing Transport by 2030 and Beyond*. This report is nearing completion and anticipated to be finalized and become publically available in mid 2020. Task 39 has contributed three deliverables ("role of biofuel policies in the increased production and use of advanced biofuels in long-distance transport sectors", "future feedstock availability and costs (international perspective)" and "potential future GHG emissions of advanced biofuels") and is assisting with finalizing the report.

- Task 39 published the report, *Comparison of biofuel life cycle analysis tools, Phase 2, Part 2: biochemical second generation (2G or cellulosic) ethanol production and distribution*
  This study was part of a project comparing leading LCA models being used to assess the sustainability of various biofuels pathways. The goal was to better understand and quantify why different leading life cycle assessment (LCA) models – the EU's BIOGRACE, Canada's GHGENIUS, USA's GREET and Brazil's VSB – give in some cases highly disparate results when they are ostensibly based on the same scenarios and use the same model inputs. This recent report focuses on cellulosic ("second generation") ethanol produced from either corn stover, wheat straw, sugarcane bagasse and/or straw, and forest residues. The full report is available at Task 39's website.

	BioGrace	GHGenius	GREET	New EC	VSB
Model version	4d (2015)	5.0a (2018)	2017	2017	2018
Developed for regulatory use	Yes	No	Yes	Yes	No
IPCC GWP method	2001	1995, 2001, 2007, 2013	2013	2013	2013
Default global warming gases	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O, CO, VOC, NOx, fluorinated compounds	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O
Lifecycle data	JRC (2008)	Internal	Internal	JRC (2017)	Ecoinvent
Functional unit	MJ	km, MJ	km, mile Btu, MJ	MJ	km, MJ
Default allocation	Energy	Mostly substitution	Variable	Energy	Economic
Land use change	C stocks	Internal model	CCLUB/GTAP	C stocks	-

- Task 39 published the report, *Implementation Agendas: 2018-2019 Update - Compare and Contrast Transport Biofuels Policies*
  IEA Bioenergy Task 39 strives to increase production and use of sustainable transport biofuels, and periodically issues its Implementation Agendas report to summarize policies being used around the world to promote greater deployment of biofuels. The 2018-2019 report update describes the current policies in use and levels of biofuels market penetration being achieved within Task 39 member countries as well as within China, which is one of the world's major countries also aspiring to increase their production and use of biofuels. The full report and its executive summary are available on Task 39's website.

In closing, we are grateful to Franziska Müller-Langer and Nicolaus Dahmen, Germany's representatives to Task 39, and their colleague, Gabriel Costa de Paiva, for co-authoring this newsletter's feature article on biofuels-related developments in Germany.

As always, we appreciate your readership and value your input and feedback. Please email us any ideas or suggestions for increasing this newsletter's value.

Thanks for reading and participating in the IEA Bioenergy Task 39 network.

Mahmood, Jim, and Jack

Biofuels Production and Consumption in Germany: Status, Advances and Challenges

Franziska Müller-Langer (Deutsches Biomasseforschungszentrum), Nicolaus Dahmen (Karlsruhe Institute of Technology), Gabriel Costa de Paiva (Deutsches Biomasseforschungszentrum)

1. Introduction

There are major challenges to achieving a CO_2 neutral society by 2050 while fulfilling sustainable development goals (SDGs). Targets, corresponding strategies and policy instruments as well as technical measures are at different stages of progress on international and national levels. In the mobility sector, enormous efforts are required as transport demand and the sector's greenhouse gases (GHG) emissions are forecast to grow if no measures are taken. This is also true for Germany, which still faces an enormous need to reduce GHG emissions from transport.

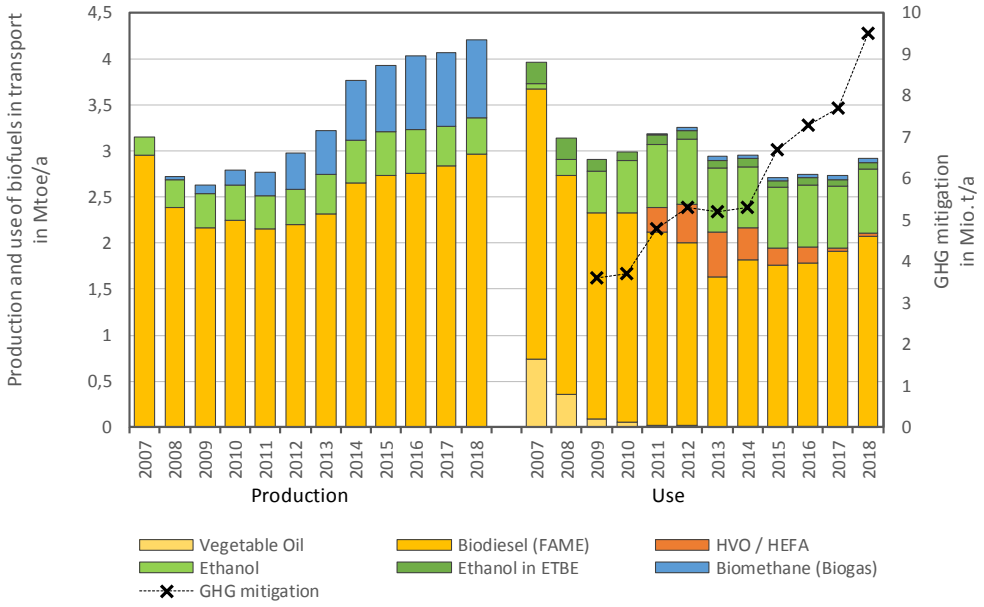
This feature article summarizes the current status of transport sector biofuels in Germany including major policy drivers, decarbonization strategies and initiatives as well as recent advances in technology development.

2. Current status of transport sector biofuels

In 2018, Germany's transport sector energy consumption (63.6 Mtoe w/o electricity) was 96% fossil fuels (52.5% diesel, 26.1% gasoline and 16.4% jet fuel, CNG/LNG about 0.2% and LPG 0.5%) and only 4.3% renewable fuels, primarily biofuels such as biodiesel (FAME) with 1.93 Mtoe and bioethanol with 0.76 Mtoe. Usage levels of other renewable fuels like vegetable oils, HVO/HEFA and biomethane were less than 0.1 Mtoe (Naumann et al. 2019; UBA 2020; FNR 2020). Lack of incentives translates into modest market demand for fuels like E85, pure FAME or vegetable oils.

Germany's biofuel sector has been heavily influenced by changing political conditions in recent years. Fig. 1 shows total production and use of biofuels in Germany from 2007 to 2018. While the fraction of pure biofuels was around 60% (2.7 million tons) of total renewable fuels in Germany in 2007, by 2018 it had dropped to well below 1%. Similarly, HVO/HEFA had a significant use share of 17% (0.47 million tons) in the middle of this period, however this declined to 1% in 2017/2018. HVO/HEFA is not produced in Germany, it is completely imported. In contrast, Germany is currently a net exporter of biodiesel (0.8 million tons). The production volumes of biodiesel (FAME) were at about the same level as domestic use until 2011. Since 2012, production volumes have been rising slightly despite decreasing biodiesel use. The biofuel market for gasoline substitutes has developed comparatively continuously and since 2011 has accounted for up to 23% (1.2 million tons) of total biofuel used (by energy content). The remaining demand is imported. Biomethane has established itself on the market and recent trends show increasing use (biogaspartner 2019). The total amount of biomethane produced and fed into the natural gas grid is significantly larger than shown in Fig. 1 but is mainly used in electricity and heating markets.

In 2018, Germany's use of biofuels avoided 9.5 million tons GHG emissions. The average specific GHG mitigation potential of biofuels within the GHG quota is 83% for biodiesel (FAME), 77% for HVO/HEFA, 86% for bioethanol and 90% for biomethane. This increase compared to 2017 is due to new fossil reference values but also to an increasing shift to using biobased residues for fuel production (mainly used cooking oil, UCO). (BLE 2019)



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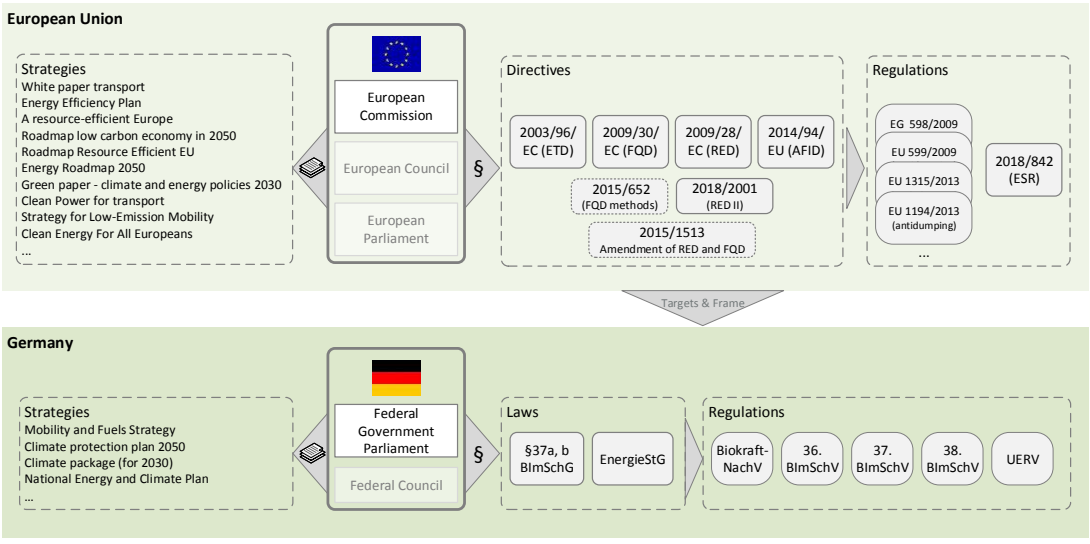
Data base: BDBe 2019, 2019; BLE 2015a, 2018; BNetzA und BKartA 2018; Destatis 2018, 2019; FNR 2019; IFRI 2019; OVID 2019a, 2019b; VDB 2015; HVO / HEFA: no production in DE; Biomethane: production also for electricity and heat sector; GHG mitigation: 2019 + 2010 35% based on RED, 2011-2017 based on BLE data

Fig. 1 Development of biofuel production and use (Naumann et al. 2019).

3. Policies driving production and consumption

A simplified overview of existing policy measures at the EU level and their national transposition in Germany is shown in Fig. 1. More detailed descriptions are provided in (Naumann et al. 2019) and (Ebadian et al. 2019).



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2009/30/EG (98/70/EC) – FQD Fuel Quality Directive | 2009/28/EC – RED Renewable Energy Directive | 2003/96/EC – ETD Energy Tax Directive | 2014/94/EU – AFID Directive on the deployment of alternative fuels infrastructure | 2018/842 (ESR) – Effort sharing regulation 2021-2030 | BImSchG: Federal Immission Control Act (§37a – Minimum shares of biofuels related to the total fuel amount in transport) | EnergieStG: Energy Tax Law | Biokraft-NachV – Biofuels sustainability regulation | 36. BImSchV – Regulation for implementation of biofuels quota | 37. BImSchV – Regulation for counting of electricity based fuels and coprocessing of biooils on the GHG quota | 38. BImSchV – Regulation for the determination of further terms regarding the GHG mitigation of fuels

Fig. 2: EU Policy framework and its transposition into German legislation (adapted from Naumann et al. 2019)

Key to fulfilling the European Union's (EU) Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) targets is the GHG-emissions based quota system that was implemented starting in 2015. It obligates fuel supplier companies to sell their respective biofuel together with its fossil counterpart gasoline or diesel (which is usually done through blending) to produce a fuel mix which achieves a 3.5%/4%/6% GHG emissions mitigation (compared to fossil gasoline

and diesel reference) for the entire fuel sector from 2015/2017/2020 onwards. The target continues after 2020 at the level of 6%. In case of non-fulfilment of these obligations, penalties of 47 EURct/kg CO_2 equivalent apply. Biofuels that are counted within the quota are fully energy taxed. Moreover, the BImSchV regulations (cf. Fig. 2) provide for a maximum limit of conventional biofuels and minimum quotas for advanced biofuels (0.05% from 2020, 0.1% from 2021, etc.), co-refining for hydrotreated oils as well as counting electricity for transport. Moreover, the Upstream Emissions Reductions (UER) ordinance, implementing EU legislation that has entered into force, allow mineral oil companies to apply UER measures to comply with legal requirements from 2020 on. Based on that, the absolute annual biofuels amount depends on the total fuel demand, the biofuel-specific GHG mitigation and the GHG avoidance through UER of up to 1.2%.

According to the German Climate protection plan in transport, the GHG emissions mitigation has to be about 40-42% until 2030 (c.t. 1990, i.e., reduction about 65-68 million tons). The general frame for renewables in transport until 2030 is set with the RED II (2018/2001/EU), targeting 14% renewable fuels in transport by 2030 that meet sustainability criteria). In addition, the Effort Sharing Regulation (ESR 2018/842), which sets binding annual emission reductions by Member States from 2021 to 2030, is important. Recently, Germany has started transposing RED II and ESR rules into national laws and regulations. The current draft Climate Action Programme 2030, which forms the base for the Climate Protection Law, will also be the basis for establishing 2030 targets.

In addition to REDII and ESR, one of the main public drivers is the EU's CO_2 regulation for vehicles. By the end of 2020, for instance, a fleet consumption limit of 95 g(CO_2)/km will apply to all newly registered passenger cars, with a fleet consumption reduction of 37.5% in 2030 targeted compared to the reference year (2021). Following this, debate shifts to electric mobility and battery-powered vehicles.

Recently, the EU's new Green Deal with its goal to reduce GHG emissions to net-zero by 2050 has come to dominate policy discussions in Brussels and Berlin, which will also influence transport fuels policies.

4. Strategies and initiatives with links to renewable (bio)fuels

Biofuels are considered to be one important renewable alternative for the transport sector out of several different alternatives, each of them further promoted by ongoing strategies and initiatives.

The most important strategies and related public funding are highlighted as follows.

The 7th Energy Research Programme issued by the Federal Government of Germany, asking for new kinds of improved fuels, e.g., biofuels from waste substances and residues, fuels from renewable electrical energy, or solar fuels. Additional innovations and technological progress are needed to grasp these opportunities. In this context, the question arises as to how and for which applications limited biogenic energy sources can best be used. Where possible, the goal must be to achieve cascading and coupling of processes for most complete and efficient use of the biogenic resource. Therefore, the combination and synergistic use of biomass and electrical power is addressed in a number of ongoing projects. Close cooperation is also aimed at with other countries both within and outside the EU, considering export strength of plant manufacturers located in Germany and through the now global supply chains for energy and fuel supply and trading (BMWi 2018).

Public funding for alternative motor fuels on the national scale is also supported by the Ministry of Transport and Digital Infrastructure (BMVI) with regard to, e.g., infrastructure, e-mobility, LNG, CNG, jet fuel, and by the Federal Ministry of Education and Research (BMBF) with the "Kopernikus Projects". Moreover, the Ministry of Economic Affairs and Energy (BMWi) is focusing on e-fuels in its "Energy transition in transport" programme. Under the Renewable Resources Funding Scheme of the Federal Ministry of Food and Agriculture (BMEL), 23 R&D projects have received funding. Examples of the main topics funded include novel routes for the production of fuels or fuel additives and adapting internal combustion engines for multiple fuels. However, bioenergy research is also influenced by the sustainability

strategy, the biomass action plan, the bioeconomy research strategy and policy strategy, as well as the forestry and wood products strategies.

To decarbonise the transport sector, high priority has been given to electro-mobility for short-distance traffic and passenger cars and to using methane as a transport fuel, e.g., like liquefied natural gas (LNG) for heavy-duty land and waterborne transport. Expert groups like the Federal Government convened National Platform Future of Mobility (NPM) are involved in these often controversial discussions.

In the context of designing and establishing a new energy system in Germany, hydrogen generation and utilization again has been identified as a possibly important component for sector coupling. Substantial funding has been provided to explore renewable hydrogen as an energy carrier for industry and fuel applications in the medium and long term. A national hydrogen strategy has been developed that is ready for approval and implementation in 2020.

Initiatives that are acting at different levels that include renewable (bio)fuels include, for instance:

- National Platform Future of Mobility with different working groups (one of them is e.g. focusing on Alternative drive technologies and fuels for sustainable mobility),
- DECHEMA ProcessNet Group on Advanced alternative liquid fuels with stakeholders from academia and industry,
- BEniVer as accompanying research for the energy transition in the traffic sector,
- Biomass energy use network supporting the Energy Research Programme,
- biogas partner with focus on biomethane
- aireg as Aviation Initiative for Renewable Energy in Germany e.V., and
- Power to X Alliance which is more related to efuels.

5. Advances in renewable (bio)fuels technologies

5.1. Conventional biofuels

As mentioned above (e.g., Fig. 1) conventional biofuels such as biodiesel (FAME) and bioethanol are the main fuels used to fullfil Germany's GHG reduction quota. A shift is occurring in greater use of biobased residues (mainly used cooking oil, UCO) and in the use of by-product CO_2 from ethanol production. Biomethane and HVO/HEFA still contribute minor shares.

5.2. Advanced biofuels

There are many projects focused on developing advanced transport biofuels. These are funded by a variety of different funding programs focused on the development and implementation of new kinds of improved fuels (e.g., biofuels from waste substances and residues, fuels from renewable electrical energy, or solar fuels), with projects spanning a wide range of technology readiness levels (TRL) or fuel readiness levels (FRL). Table 1 summarizes some of the most important research projects being carried out in Germany at pilot plant or demonstration scale levels.

Table 1 Pilot plant and demonstration level transport biofuels research projects in Germany (examples)

Type of biofuel / conversion route	Process characteristics,	TRL/FRL; Capacities	Stakeholder in research and industry in Germany
Pyrolysis to intermediate products	Flash pyrolysis of different biomasses, slurry production	bioliq® demo plant, 2 MW pyrolysis, TRL 5	KIT
Hydrothermal processes to intermediate products	Bioethanol & Chem. | wood; lignocellulose pre-treatment (organosolv method), fermentation, enzyme production, organosolv lignin, sugars (for ethanol and various platform chemicals)	Fraunhofer CBP pilot plant in Leuna, operational since 2013, TRL 4-5 lignocellulose pre-treatment: 1 t wood/week, expanded in the period 03/2016-09/2019.	Fraunhofer CBP, DBFZ, Thyssen, Linde Engineering
	Hydrothermal liquefaction	Lab / technical plants, TRL 3	DBFZ, KIT, Uni Hohenheim, TI
	Hydrothermal liquefaction & gasification	Pilot plant Verena, TRL 5-6	KIT
BTG | Syngas for Methanol, chemical products	Pre-treatment, gasification, and syngas formation	TRL 6-7 – Demonstration Plant – 25.000 tons from coal, waste or residues processed per Year (planned for 2021)	Merseburg University of Applied Sciences, Fraunhofer CBP and others
BTL | H_2-rich synthesis gas, bio-coal and liquid bio-oil	Thermo-Catalytic Reforming (TCR©), Pressure Swing Adsorption and Hydro Deoxygenation	TRL 6-7 – Demonstration Plant (1/5/2017 – 30/4/2021) in Sulzbach-Rosenberg	Fraunhofer CBP (Coord.), Zweckverband Müllverwertung Schwandorf and others
Bioethanol (fermentation)	cellulosic ethanol from agricultural residues like wheat and maize straw	Demo plant sunliquid® in Straubing, operational since 2014, TRL 7, FRL 6 1,000 t/a (from 4,500 t/a straw). Building a 50.000 t/aplant in Romania and signed license agreement in Slovakia and China.	Clariant
	Bioethanol from corn-stover, grass and other agriculture waste	TRL 4-5 – Pilot Plant (30 t/y) – focus on development of a commercial yeast for cellulosic ethanol (Bacovsky 2020).	Lesaffre (aquired Butalco plant in Stuttgart)
Isobutene (fermentation)	Fermentation	Demonstration plant (TRL 6)	Fraunhofer CBP / Global Bioenergies
HVO/HEFA	Hydrotreating processes, different feedstocks	Technical units, TRL 2-3	TU Bergakademie Freiberg (TUBAF), VT Schwedt
HCVO (Hydrotreated Cracked Vegetable Oil)	2-step process for different feedstocks: 1st step = SRD (Solvolytic Reactive Distillation) for cracking and deoxygenation: intermediate product = CVO (Cracked Vegetable Oil) 2nd step = hydrotreating: product = HCVO	TRL 6 pilot project (X-Energy/READi™-PtL project) 2019-21: capacity of SRD READi™ process pilot plant = 2 tons per week UCO; plant under construction (planned commissioning 2021)	HAW Hamburg, Nexxoil, KBS Krebs Brüggen Sekundärrohstoffe
BTL | Methanol / DME /gasoline	bioliq process, fast pyrolysis, entrained flow gasification, hot gas cleaning, synthesis	5 MW gasification 40-80 bar (TRL 6-7), 2 MW gasoline synthesis (TRL 7)	KIT, CAC, Air Liquide
BTL | Fischer-Tropsch	Micro-structured reactor module	2-50 bpd container plant, TRL 5, syngas transfer from bioliq plant	KIT/INERATEC
BTL | Kerosene	Thermo-Catalytic Reforming (TCR©), Pressure Swing Adsorption, Hydro Deoxygenation and Hydro cracking/ isomerization	TRL 6-7 – Demonstration Plant – Scale and Location to be determined (probably near TCR© Susteen plant)	University Birmingham (Coord.), Fraunhofer Umsicht, Susteen Technologies, BIGA Energie GmbH, and others

Type of biofuel / conversion route	Process characteristics,	TRL/FRL; Capacities	Stakeholder in research and industry in Germany
BTG | FT Liquids	Pre-treatment, gasification, syngas formation and FT Synthesis	TRL 4-5 – Pilot plant. Utilization of infrastructure from TUDA pilot plant in Darmstadt with other modules. Planning construction	TU Darmstadt, Aichernig Engineering GmbH, and others
XTL | Methanol, gasoline	HP-POX gasifier (Since 2003), FlexiSlag gasifier (since 2013) and GSP gasifier (since 2018). STF Gasoline pilot plant since 2010	TRL 6-7 - 5 MW (gasifier) and 10 MW (synthesis) and 120 L/h gasoline output by the STF gasoline pilot plant, which can also synthetize methanol	TUBA Freiberg, Air Liquide, CAC
HTL | Hydrothermal liquid biofuels	2-stage hydrothermal liquefaction, refining	Technical plant, TRL 4	DBFZ and partners
Biomethane via biogas (fermentation)	straw fermentation, fertilizer production; (additional: Bioethanol plants (grain, sugar beet) and biogas	Commercial plant, 16,5 MW (136 GWh/a) from 40 kt/a straw, TRL 8, FRL 8 (260 kt/a bioethanol + 480 GWh biomethane)	VERBIO AG
Biomethane via SNG	Gasification, gas conditioning, methanation	Plant units at technical labs	KIT/EBI, Uni Erlangen, DBFZ, ZSW, CUTEC
	Gasification, catalytic honeycomb methanation (mobile container), compression	TRL 5, 60 kW (CH_4)	DVGW/EBI, KIT/EBI
Bio-LNG	Gasification or renewable CO_2 + H_2O-electrolysis, catalytic three phase methanation	TRL 5, 100 kW (CH_4)	KIT/EBI
	High pressure fermentation + electrolysis + biological methanation + liquefaction	TRL 5, 15 kW (CH_4)	Uni Hohenheim, DVGW-EBI
Biomethane (Bio-CNG/LNG)	Anaerobic fermentation in combination with hydrothermal processes and methanation	Technical pilot plant by end of 2021 including components with TRL 4 - 9	DBFZ, UIT
Different fuels	Fuel science center (formely Tailor-made fuels from biomass) Biomass pretreatment; enzymatic + catalytic biomass processing; synthesis and conversion to platform molecules and fuels;	Lab units	RWTH Aachen, Fraunhofer IME, Max-Planck-Institute

5.3. Other renewable fuels

Power-based fuels (PtX or e-fuels) have attracted particular attention in Germany´s energy transition for mobility. Through the Federal Ministry for Economic Affairs and Energy's funding initiative "Energy transition in the transport sector", fifteen research associations have been formed to work on different aspects of the production and utilization of innovative, power-based fuels. Methane, diesel, gasoline, marine and aviation fuels are covered; synergistic use of biomass as carbon or hydrogen source is also considered here. (BMWi 2020).

As an example, within the project C^3 Mobility, the STF (Syngas-to-Fuel) plant at TU Freiberg (Fig. 3) produced a first batch of 16,000 Liters of synthetic gasoline based on green methanol at the end of 2019. In 2020, a similar amount of fuel will be produced for engine and vehicle testing (CCCM 2020).

In some of the projects, process layouts and design concepts for power-to-fuels demonstration plants are elaborated, such as in the KEROSyN100 project to produce renewable aviation fuel or in refinery integrated Fischer-Tropsch synthesis which make use of the refinery´s CO_2 emissions and co-processing of the so-derived hydrocarbons.

Fig. 3 The Syngas-to-Fuels (StF) plant at (© TU Bergakademie Freiberg, IEC, 2014)

The Federal Ministry of Education and Research (BMBF) also funds the Kopernikus P2X project which has more than 40 stakeholders within Germany. This project is divided in 3 phases over 2016-2026 and aims to develop solutions with which, using renewable energy, energy sources are flexible in terms of their ability to meet dynamic social needs in a coordinated manner (BMBF 2020).

The Federal Ministry of Economic Affairs (BMWi) has implemented "Regulatory sandbox" projects as test environments for innovation and regulation with a clear focus on hydrogen and PtX (BMWi 2019).

In the project "reFuels – Rethinking Fuels," the efficient production and use of regenerative fuels, so-called refuels, are studied in an initiative of KIT Karlsruhe together with the Baden-Württemberg Ministry of Transport, three other state ministries, and several partners from automotive, automotive supply, and mineral oil industries (reFuels). Around 2,000 Liters each of gasoline and diesel fuels are being produced by biomass-to-liquids (gasoline) and power & carbon dioxide-based Fischer-Tropsch synthesis (diesel). In addition, project partners test the use of reFuels in the existing vehicle fleet in order to achieve faster agreement within society to accept these lower carbon fuels. This project covers the entire value chain, from utilities to fuel synthesis, to suppliers, to systems developers, to engine and car manufacturers. Scenarios combining possible carbon sources, types of fuels, electricity grid and production sites will be evaluated for optimum production and use of renewable fuels in Germany.

The fuels in the refuels project are produced by making use of two Infrastructures erected at KIT. The bioliq plant producing bio-based gasoline fractions (Fig. 4) and the still extended EnergyLab2.0. In the latter, research on the interaction of components for future energy systems and testing of new approaches to stabilizing energy grids is investigated including the transformation of electrical power into chemical fuels based on the production of renewable power and hydrogen as well as carbon dioxide capture and conversion (Fig. 5).

Fig. 4 The bioliq plant for synthetic gasoline production from biomass at KIT (© KIT, 2018)

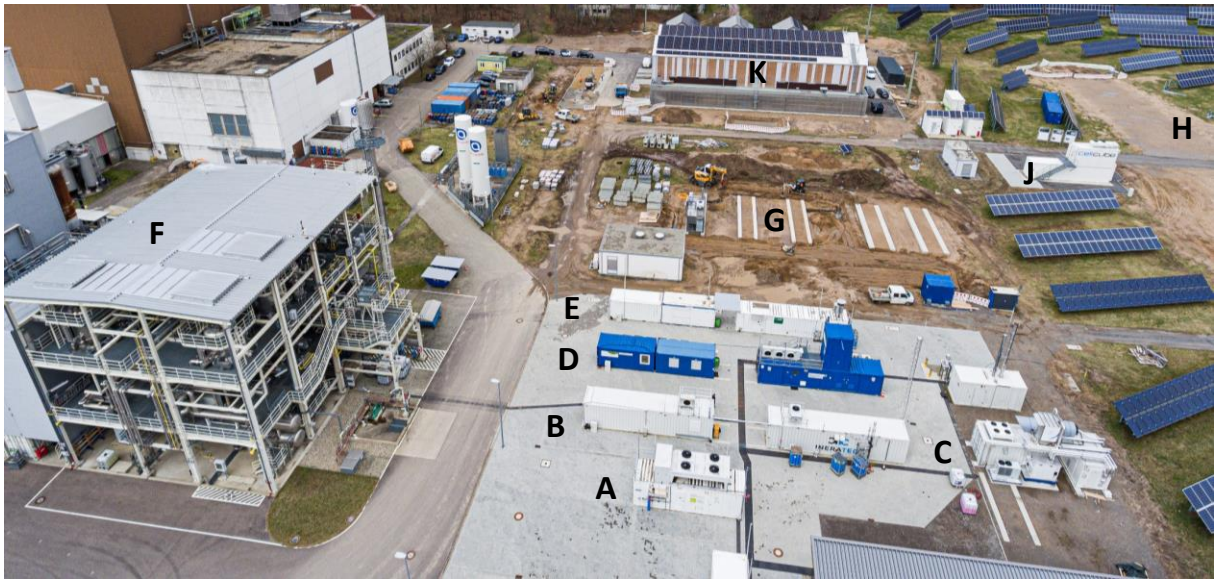

Fig. 5 EnergyLab 2.0 with different power-to-gas and power-to-fuel container plants (© KIT, 2020), A: Siemens PEM electrolyzer, B: INERATEC Fischer-Tropsch synthesis, C: Climeworks Direct Air Capture, D: Methanation three-phase reactor, E: Methanation honeycomb reactor, F: bioliq methanol-to-gasoline plant, G: Solid oxide electrolyser under construction, H: 1 MW photovoltaic plant, J: electrical storage systems, K: Control center

A more recent focus is on waste-to-fuel strategies (or recycled carbon fuels), stimulated by the EU´s and national renewed emphasis on circular economy concepts, with a focus on chemical recycling prior to energetic use. In fact, of an estimated 5.9 Mio t/a of plastic waste generated, little more than half is combusted, with most of the rest for recycle products of lower quality. Decomposition to platform molecules as building blocks chemicals and fuels are practically not established. Therefore, thermal depolymerization of plastics is studied to produce fuel components, supported by catalytic process steps to increase product quality. A prominent example is OMV´s ReOil process in Austria, demonstrated for co-processing in a refinery at the scale of 100 Liters of bio-crude per hour. Pyrolytic and gasification pathways are being studied and compared for making use plastic waste compositions available in Germany (Stapf et al. 2019).

6. Prospects of biofuels in Germany

Market developments for renewable (bio)fuels are mainly set by policy. Stronger policy support by market incentive programmes as well as a greater rate of innovation will be required to reduce the cost of developing and scaling up sustainable fuel production. In fact, fulfilment of Germany's climate protection plan (requiring about 40% GHG reduction in transport by 2030) will require a significant reduction in final energy demand as well as a higher share of renewables in the transport sector, which can only be achieved when several fuel options are considered in addition to e-mobility and other measures. At the latest, new production facilities and infrastructure for advanced fuels including BTL/PTL will be required from 2021 (Meisel et al. 2020). There is a urgent need to elaborate the support framework and formulate reliable ramp-up scenarios.

Not only is the production of advanced fuels important, but also a variety of supplementary work. This includes, for example, fuel blending and testing in view to fit the standards, the adaption and extension of existing norms, development of adequate fuel analysis and testing devices and protocols (which are generally optimized for fossil fuels and not necessarily well-suited for other types of fuels), and many other time consuming, often underestimated aspects of feedstock provision, fuel production and market implementation.

Despite the EU's Green Deal and related directives and regulations and their national transposition, it is very likely that the GHG emissions reduction quota will be continued after 2021, with additional CO_2-related instruments also coming into effect. Measures discussed above to promote e-mobility, methane as well as hydrogen as transport fuels, will in general have a positive impact on the market however not necessarily for biofuels. Of course, the Covid-19 pandemic also has and will have heavy impacts on all issues related to sustainable survival and development. These risks will discourage fuel producers and the related market.

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In the News

Reports and Research

- January – Researchers from the Lawrence Livermore National Laboratory issued a report naming three pathways that would help California achieve its aim of becoming carbon-neutral and eventually carbon-negative by 2045. These strategies include conversion of waste biomass to fuels while capturing carbon dioxide during the process, restoring natural ecosystems and using direct air capture machines (Read more).
- March – The IEA Bioenergy News Bulletin for March is available at: https://www.ieabioenergy.com/publications/iea-bioenergy-news-bulletin-march-2020/
- April – To help drive decarbonization strategies, ABS has published Setting the Course to Low Carbon Shipping: Pathways to Sustainable Shipping, the second in a series of industry outlook documents — the first was published in June 2019 — to reference available carbon-reduction strategies and inform the shipping industry as it enters the uncharted waters of the 2030/2050 emissions challenge (Read more).
- April – The BIOFIT consortium recently published a handbook on "Technical options for retrofitting industries with bioenergy". The handbook includes arguments for retrofitting, describes the retrofitting process and its impact on public perception, summarizes the European biomass potential and logistics of biomass, provides an overview on biomass conversion pathways, and finally, explains technical retrofitting solutions for industries. The addressed industries are first-generation biofuels, pulp and paper, fossil refineries, fossil firing power and Combined Heat and Power (CHP) sectors (Read more).
- May – The IEA Bioenergy Annual Report 2019 was published]. It includes a special feature article on 'Gasification – a versatile technology' prepared by IEA Bioenergy Task 33. It also provides Tasks' progress updates, including recently completed reports, papers, workshops. Information about inter-task projects, task participation, contracting parties, budget tables as well as key IEA Bioenergy contacts (Read more).
- May – On September 15, 2011, NHTSA and EPA finalized joint Phase I rules to establish a comprehensive Heavy-Duty National Program to reduce greenhouse gas emissions and fuel consumption for on-road medium- and heavy-duty vehicles. As NHTSA and EPA began working on a second round of standards, the National Academies issued another report, Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report, providing recommendations for the Phase II standards. This third and final report focuses on a possible third phase of regulations to be promulgated by these agencies in the next decade (Read more).

Policy and Regulatory Developments

- January – Reuters reports that China has abandoned its plan to roll out a nationwide E10 ethanol mandate this year, citing a corn shortage and production constraints. Despite widespread belief throughout the 2010s that China's ability to command its economy made the mandate a no-brainer, some of the usual constraints were evident in terms of feedstock and refining capacity — simply, not enough was planted or built (Read more).
- January – In New York state, a coalition of private sector and civil society created the New York Clean Fuels Coalition to urge the state to implement a Low Carbon Fuels Standard similar to California and Oregon (Read more).
- January – The UK's Department of Transportation announced funding to support building four new advanced biofuel plants to covert household waste, unused straw from farmland, old wood and other biomass feedstocks into transportation fuels (Read more).
- February – According to a government announcement, the U.S. Department of Agriculture is aiming for biofuels to make up 15 per cent of transportation fuels by 2030, and 30 per cent by 2050, by increasing the production of renewable energy feedstocks (Read more).
- March – U.S. EPA approved Ace Ethanol's Part 80 registration for its new D3MAX facility at Ace Ethanol LLC in Stanley, Wisconsin. To participate in the Renewable Fuel Standard (RFS) program and generate renewable

identification numbers (RINs), renewable fuel producers must meet the registration requirements in Title 40 CFR Part 80. With the EPA approval, Ace Ethanol can now also produce cellulosic ethanol from corn kernel fiber and generate D3 RINs (one D3 RIN is generated for each gallon of cellulosic ethanol produced) (Read more).

- March – Electric vehicles groups, biofuels supporters, agriculture associations and others are coming together to promote a low-carbon fuel standard for the Midwest in an initiative led by the Great Plains Institute. This coalition seeks to move beyond disagreements and find a policy neutral solution to decarbonizing the region's transportation (Read more).

- March – In Indonesia, this year's B30 biodiesel mandate will require 9.6 billion liters of biodiesel, which will in turn reduce export availability by 3 billion liters. The industry minister said that doing so will increase the value of palm oil by $930 million while reducing fossil fuel imports, which represent a significant drain on foreign exchange reserves, by $4.5 billion (Read more).

- March – Oregon state Govenor Kate Brown signed an executive order on March 10 that sets a new goal for greenhouse gas (GHG) reduction and outlines several steps the state will take to combat climate change, including expanding Oregon's Clean Fuels Program (Read more).

- April – The IEA Bioenergy Technology Collaboration Program (TCP) announced that the People's Republic of China has joined the TCP, bringing the number of contracting parties to 26. Initially China plans to join two IEA Bioenergy tasks: "Energy from Biogas" (Task 37) and "Climate and sustainability effects of bioenergy within the broader bioeconomy" (Task 45). (Read more).

Industry News

- January – Shell Aviation and World Energy inked a collaboration to develop a scalable supply of sustainable aviation fuel. The agreement is intended to be a multi-year collaboration, with both companies acknowledging that the path to lower carbon emissions in aviation requires long-term commitment and collaboration (Read more).

- January – Clariant, Anhui Guozhen Group, and Chemtex Chemical Engineering signed a license agreement on sunliquid cellulosic ethanol technology. This is the third commercial license for the sunliquid technology and the first for China (Read more).

- January – Estonia has increased its biofuel blending mandate to 10% in line with the European Union's Renewable Energy Directive with a minimum of 6.4% of biofuel in any given liter of fuel. Although the new policy has just come into effect, already amendments to the law have been approved and are awaiting implementation that will provide fuel retailers with more flexibility in order to achieve the new national mandate (Read more).

- February – In New Mexico, Applied Research Associates, Inc. (ARA) and Chevron Lummus Global LLC (CLG) are working toward a more sustainable future by developing novel solutions to meet the global need for sustainable aviation fuels. The team is proud to announce that ASTM International has approved the new production pathway for Sustainable Aviation Fuel (SAF) called "Catalytic Hydrothermolysis Jet," or CHJ. ASTM D7566 Annex A6 was approved on Dec. 15 and was published in the revised specification for "Aviation Turbine Fuel Containing Synthesized Hydrocarbons," ASTM D7566-19b on January 29 (Read more).

- February – In Finland, Neste and IKEA Finland are offering lower emission home deliveries for Finnish consumers as IKEA gradually started using Neste MY Renewable Diesel in its home deliveries in the Helsinki capital region and around Raisio, a town in south-western Finland (Read more).

- February – In the Netherlands, the Port of Rotterdam reported that the first time, the sale of biofuel bunkers – bunker fuel to which a certain percentage of biofuel has been added – is clearly visible in its annual sales figures. Throughout 2019, 2% of sales of fuel oil and 0.5% of distillates (MGO – gas oil – and MDO – diesel oil) concern

biofuel bunkers. Sales of biofuel bunkers increased in the fourth quarter in particular. The admixture percentages of these bunkers vary between 5 and 50%. Most common is 20-30% (Read more).

- February – In Japan, Japan Airlines, Marubeni, JXTG Nippon Oil and Energy and JGC Japan have agreed to jointly conduct a feasibility study on Sustainable Aviation Fuel production and sales in Japan through the use of industrial and municipal waste, including plastic waste. In this joint study, the parties plan to evaluate the feasibility of the entire supply chain with respect to creating SAF from industrial and municipal waste, including middle and low grade plastic waste, by applying the process and technology of Fulcrum BioEnergy (Read more).

- February – In Colorado, Gevo, Inc. has been awarded A$159,000 (US$104,686) part of The Queensland Waste to Biofutures (W2B) Fund to support the development of waste to biofutures projects in Queensland, Australia. The W2B fund provides targeted funding for pilot, demonstration or commercially scalable biorefinery projects in Queensland that use conventional waste streams or biomass to produce bioenergy, biofuels and high-value bioproducts (Read more).

- February – Södra has built the world's first plant for commercial biomethanol, a sustainable fuel from forest biomass, at Södra's pulp mill in Mönsterås. Over the next few days, a first pilot delivery will go to Emmelev A/S, a customer that will be using biomethanol in its biodiesel production (Read more).

- February – Delta is making a $1 billion commitment over the next 10 years to mitigate all emissions from its global business going forward. Their goa is to invest the money in driving innovation, advancing clean air travel technologies, accelerating the reduction of carbon emissions and waste, and establishing new projects to mitigate the balance of emissions (Read more).

- February – In Canada, FORGE Hydrocarbons announced an equity investment from Shell Ventures and a follow-on contribution from Valent Low-Carbon Technologies, which will help build a first-of-its-kind CAD$30 million commercial-scale, biofuel production plant in Sombra, Ontario (Read more).

- March – Pyrocell AB, the joint venture between wood products major Setra Group and oil refiner and renewable fuel producer Preem AB, has held a groundbreaking ceremony at Setra Kastet sawmill in Gävle marking construction start of Sweden's first pyrolysis plant to convert sawmill residues into a biocrude for advanced biofuels production (Read more).

- March – International technology group ANDRITZ has started up a fossil-free biomethanol plant at the Södra Cell Mönsterås pulp mill in south-east Sweden. The global company is using its self-developed A-Recovery+ concept that delivers commercial grade biomethanol by using a patented extraction process (Read more).

- March – The Croatian oil and gas company INA has awarded Axens (Rueil Malmaison, France; www.axens.net) a license agreement to supply Futurol cellulosic ethanol technology and contract for basic engineering design of an advanced bioethanol production plant in Sisak, Croatia (Read more).

- March – Finland, Finnair and Neste inked a new agreement which will gradually and considerably increase Finnair's use of sustainable aviation fuel in its operations. The new partnership will be a key contributing factor in Finnair's long-term target of carbon neutrality. Sustainable aviation fuels are a key part of the long-term solution for reducing the CO_2 footprint of aviation, as they reduce the CO_2 emissions by up to 80% compared to fossil fuels (Read more).

- March – In Brazil, the National Agency of Petroleum, Natural Gas and Biofuels (ANP) approved the results of the 71st Biodiesel Auction, in a step that formalizes the requirement to begin blending 12% biodiesel in commercial diesel, according to the Brazilian Association of Vegetable Oil Industries (Abiove) (Read more).

- April – Natural Gas Vehicles for America (NGVAmerica) and Coalition for Renewable Natural Gas (RNG Coalition) announced that 39% of all on-road fuel used in natural gas vehicles in calendar year 2019 was renewable natural gas (RNG) (Read more).

- April – Recent announcements by Southern California Gas (SoCalGas) indicate renewable natural gas (RNG) will increasingly contribute to efforts to decarbonize California's transportation fuel sector. RNG's share of natural gas supply in California's transportation sector grew from approximately 10% in 2013 to 70% in 2018, reaching more than 30 million diesel gallons equivalent, or about 45 million cubic feet per day, for the first time during the third quarter of 2018 (Read more).

- April – In Germany, Bavarian ship management company MINSHIP and its subsidiary MINMARINE said a bulk carrier in their fleet of managed vessels, M/V Trudy, has successfully bunkered GoodFuel's biofuel at the Port of Rotterdam. The biofuel bunkered by the 2009-built, 30,790-dwt bulk carrier on April 17 was GoodFuels' sustainable Bio-fuel Oil MR1-100, which is an advanced sustainable biofuel produced from certified waste or residue feedstocks (Read more).

- April – In Sweden, Preem has chosen Haldor Topsoe's HydroFlex renewable fuel technology to produce renewable diesel and jet fuel at their Gothenburg refinery in Sweden. The 16,000 barrels-per-day unit will have a yearly production capacity of approximately one million cubic meters of fuels which corresponds to about 25% of Sweden's estimated annual consumption of renewable fuels in 2030. This volume of renewable fuel can reduce emissions from cars and planes by 2.5 million tons CO_2 every year (Read more).

Upcoming Meetings, Conferences & Webinars

Note: Due to the coronavirus pandemic, which has resulted in severe restrictions on travel and physical meetings, the dates of the following conferences and meetings may change. Please check their websites to learn about the latest status of these conferences and meetings.

2020

June

- International Conference on Biotechnology, Bioengineering, Agricultural and Biosystems Engineering, June 11-12, Tokyo, Japan
- International Conference on Bioengineering, June 22-23, Venice, Italy

July

- International Conference on Biofuels and Biochemicals Production, July 15-16, Copenhagen, Denmark
- International Conference on Biofuels and Bioenergy Systems, July 16-17, Toronto, Canada
- International Conference on Biomass Pretreatment Methods, July 16-17, Bali, Indonesia

September

- International Conference on Sustainable Biofuels and Bioenergy, September 3-4, Prague, Czechia
- Future of Biofuels, September 22-23, Copenhagen, Denmark
- Advanced Biofuels Conference, September 15-17, Stockholm, Sweden

October

- Biofuels International Conference and Expo, October 6-7, Brussels, Belgium
- 2nd International Conference on Biofuels, Bioenergy and Bioeconomy, October 19-21, Vancouver, Canada

November

- International Conference on Biomass Pretreatment and Process Development, November 9-10, Dubai, United Arab Emirates
- International Conference on Biofuels, Bioenergy and Biotechnology, November 17-18, Tokyo, Japan
- International Conference on Biomass Pretreatment and Hydrolysis, November 19-20, London, United Kingdom
- 5th International Conference on Biofuels and Bioenergy, November 23-24, Edinburgh, Scotland

December

- 10th International Conference on Algal Biomass, Biofuels and Bioproducts, December 7–9, Pittsburgh, USA
- International Conference on Biofuels and Bioenergy Technologies, December 17-18, Kuala Lumpur, Malaysia
- International Conference on Industrial Biotechnology and Bioenergy, December 28-29, Paris, France

IEA Bioenergy Task 39 Meetings

IEA Bioenergy Task 39 is reviewing its plans on future meetings in light of the global COVID-19 pandemic and travel and gatherings being highly curtailed. At this juncture, Task 39 is still planning to hold its the next business meeting in Germany on 26-27 November, 2020. In addition, in 2021 Task 39 plans to have its first business meetings in Denmark on 21-23 April, 2021, and its second in Australia in late 2021 (dates still be to finalized) in combination with the end of triennium IEA Bioenergy meeting and conference.

Please contact us for more detailed information about the Task's future business meetings.