

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

Task 39
IEA Bioenergy

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From the Task

By Mahmood Ebadian, Jim McMillan and Jack Saddler

Since publishing our last Newsletter, 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.

Business meeting in Stockholm, Sweden

Task 39's second business meeting of the 2019-2021 triennium was held 16-17 September in Stockholm in conjunction with Sweden's [2019 Advanced Biofuels Conference](#) held there 17-19 September. This meeting focused on reviewing the Task's ongoing and recently completed work and proposed future work activities for the 2019-2021 triennium. The main discussion points are summarized below:

Task 39's main focus remains on drop-in biofuels for heavy duty transport, i.e., transport sectors where substantial electrification isn't foreseen in the near-to-mid-term. It is recognized that beyond on-going technical innovation, effective policies will have to be developed and implemented to establish economically viable drop-in biofuels. The Task is especially interested in advancing biofuels for marine and aviation applications, partly because both of these transport sectors are highly international in addition to each having its own unique characteristics and challenges. Future work in this area will include: a) assessing the various methods used to measure/follow the "green" molecules when adopting co-processing and upgrading strategies within existing petroleum refineries; and b) extending Techno-Economic Assessments (TEA) and Life Cycle Analysis (LCA) studies of leading and proposed routes to drop-in biofuels production. Task 39 will update its previous reports on "[Biofuels for the marine shipping sector](#)" and "[Drop-in Biofuels](#)". In the meantime, the most recent 2018-2019 drop-in biofuels report will form the basis for establishing future collaborations with other Tasks such as Task 33 (Gasification), Task 34 (Direct Thermal Liquefaction), Task 43 (Feedstocks) and Task 45 (Climate and Sustainability) as well as with allied organizations such as IEA HQ, IRENA, GBEP, etc.



Task 39 Members - ExCo* and Task Representatives

Australia

Mark Brown*
Steve Rogers

Austria

Ing. Rene Albert*
Dina Bacovsky

Brazil

Miguel Ivan Lacerda de Oliveira*
Glauca Souza

Canada

Alex MacLeod*
Jack Saddler

Denmark

Ane Katharina Paarup Meyer*
Henning Jørgensen
Sune Tjalfe Thomsen
Michael Persson

European Commission

Kyriakos Maniatis*
Laura Lonza
Adrian Oconnell

Germany

Birger Kerckow*
Franziska Müller-Langer
Nicolaus Dahmen

Ireland

Matthew Clancy*
Stephen Dooley

Japan

Seiji Morishima*
Shiro Saka
Yuta Shibahara

Netherlands

Kees Kwant*
Paul Sinnige
Timo Gerlagh
Johan van Doesum

New Zealand

Paul Bennett*

Norway

Trond Vaernes*
Duncan Akporiaye

South Korea

Seungchan Chang*
Jin Suk Lee
Kyu Young Kang
Seonghun Park

Sweden

Asa Forsum*
Tomas Ekbohm
Leif Jonsson

United States

Jim Spaeth*
Jim McMillan



Image Source: esf.edu.com

Task 39 will continue 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 contributions of LCA experts and the biofuel industry attending the recent [the EU's Joint Research Center-Task 39 sustainability workshop](#) helped to further focus Task 39's work proposed for this area. Proposed future activities include developing complete high-quality data sets for LCA models and making these data sets available to model developers/users to incorporate into their assessments; developing white/peer-reviewed papers on implications of using different allocation methods; and developing a position paper on the best practices for doing an LCA for co-processing applications. Task 39 is organizing a biofuels LCA session at the [BBEST](#) meeting being held March 30- April 1, 2020 in São Paulo, Brazil where updates and progress on LCA-related issues will be presented.

Techno-economic Assessment or Analysis (TEA) of co-processing will be another focus of Task 39 in the current triennium. Assessing methods to reliably/accurately/cost effectively "track the green molecules" will be another focus, and in this area Task 39 will strive to involve both oil refineries and regulatory bodies such as the California Air Resources Board (CARB) that are actively evaluating prospective methods for quantifying the renewable content of mixed fuels containing both renewable biogenic and non-renewable fossil fractions. To conduct both LCA and TEA projects, Task 39 will likely collaborate with Task 43 (feedstocks) and Task 45 (sustainability) to better understand the cost of sustainable feedstocks and their associated impacts on the economics and GHG reduction potential (and other sustainability attributes) of producing drop-in biofuels via coprocessing or dedicated production.

Updates on Sweden's biofuels technologies and policies

Thanks to Tomas Ekbohm, Sweden's Task 39 country representative/national team leader, representatives from several Swedish governmental organizations presented during the morning of the second day of the Task meeting. The presenters shared recent updates on the status of Swedish gasification- and pyrolysis-based technologies for biofuels as well as Sweden's current technology-push and market-pull biofuels policies and climate investments. The main takeaway messages include:



Image Source: Canola Council of Canada

- Despite the technical success of several pilot and demonstration gasification plants in Sweden, pyrolysis-based production routes to drop-in biofuels are currently favored within Sweden's new emissions reduction obligation scheme.
- The Swedish Energy Agency funds biofuels projects in Sweden. Their total yearly budget is about 140 million €, with a similar contribution coming from the involved industry. The agency's funding scope is broad, ranging from fundamental research to demonstration and introduction on international markets. The annual budget for biofuels research is 4 million €, with primary focus on development and improvement of processes for producing biofuels from lignocellulose and lignin. Funded projects favor TEA and other computer/paper studies as the budget is insufficient to support extensive experimentation, however funding support is also being provided for R&D infrastructure at pilot/demo scale, and for biorefinery pilots focused on pretreatment and biological conversion (technology push policy).

We welcome your feedback. Please direct your comments to [Mahmood Ebadian](#)

- Sweden has a fuel tax exemption/reduction policy to encourage the production and use of biofuels. The tax exemption has varied from full to reduced tax exemption however since January 2018 all biofuels have been fully exempted (market pull policy).
- Since July 2018, a quota mandate system is in place that mandates reductions in carbon dioxide emissions, with reduction targets of 2.6% for petrol-type fuels and 20% for diesel-type fuels by December 2019 (market pull policy).
- In 2018, a public inquiry was conducted on sustainable aviation fuels to analyse how best to promote aviation's use of sustainable biofuels with low lifecycle emissions. Sweden is introducing a GHG emissions reduction quota for aviation fuel in 2021. This reduction quota will apply to all fueling at Swedish airports, i.e., for both domestic and international flights.
- The Klimat Klivet (Climate Leap) initiative is a state program to foster local climate investments, with total funding of SEK 6-10 billion for the period 2015–2020. This program supports investments that can reduce emissions and influence the transition to a low-carbon economy. It targets funding actions that will have the greatest effect on reducing GHG emissions.
- In addition to investing in low-carbon transport fuels and efficient vehicles and operations, as part of its strategy to realize a transport efficient society, Sweden is also investing to achieve an increased share of transport by walking, cycling and public transport.
- RenFuel, a Swedish biofuels company, also presented on their progress developing and deploying their technology. They have a patented catalytic process that energy efficiently transforms lignin from pulp industry black liquor into renewable lignin oil (**LIGNOL®**). The company has developed 15 patent families covering over 40 countries and spends 15-20% of its R&D budget on annually on maintaining and securing intellectual property rights.

In the afternoon of the second day, most Task 39 members participated in a study tour, visiting both the Henriksdal biogas production and upgrading plant in Stockholm and Scania's engine manufacturing/assembly plant in Södertälje.

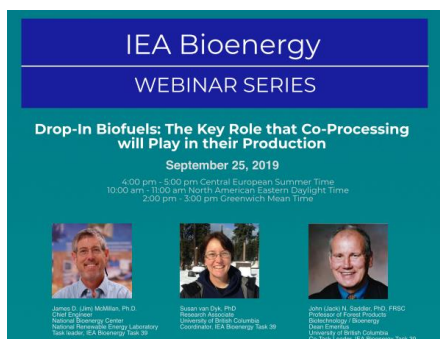
On 18-19 September, a subset of Task 39 membership also attended and presented at Sweden's [Advanced Biofuels Conference 2019](#). The conference was hosted by the Swedish Bioenergy Association and 200 participants from 24 countries participated. A summary of the presentations and project investment news is published in the October issue of [Bioenergy International](#).

Recent publications progress and information dissemination activities (September-December 2019)

- Task 39 is continuing to contribute sections to two IEA Bioenergy InterTask project reports (under Task 41) now nearing completion, 1) Advanced Biofuels - Potential for Cost Reduction; and 2) The Contribution of Advanced Renewable Transport Fuels to Decarbonizing Transport by 2030 and Beyond. These reports are anticipated to be finalized and become publically available in early 2020. A workshop on the Decarbonisation of Transport was held 18th November 2019 in Brussels. The workshop provided information on the availability of renewable transport fuels and related costs and GHG emissions, investigated the role renewable transport fuels have to play in order to reach national GHG emission reduction targets in Finland, Germany, Sweden, USA and Brazil, and discussed whether we are on track to achieve the 2030 targets. All workshop presentations are available online here: <https://iea-amf.org/content/news/TD-WS>.
- Task 39's co-leader and Canada's representative, Dr. Jack Saddler, and his research team at the University of British Columbia in collaboration with the engineering company NORAM recently completed a three-year project entitled, "Assessment of Likely Technology Maturation Pathways for Biojet Production from Forest Residues". This project was carried out under the mantle of Canada's Green Aviation Research and Development Network (GARDN) and also involved a consortium of aviation industry stakeholders including Boeing, WestJet, SkyNRG and Bombardier. Results

show that thermochemical liquefaction technologies offer viable routes to producing fuels, including biojet fuel, with significantly lower carbon intensities than petroleum-derived jet fuels. The full report and an executive summary are available at [Task 39 website](#).

- Task 39 presented highlights from its recent update of the drop-in biofuel report, “Drop-in Biofuels - The key role that co-processing will play in its production” in an IEA Bioenergy Webinar on September 25. The presentation was given by Task 39 Leader, Dr. Jim McMillan, co-leader, Dr. Jack Saddler and former Task 39 coordinator, Dr. Susan van Dyk. More information about this webinar can be found [here](#).



- Task 39 members Franziska Müller-Langer and Dina Bacovsky, respectively Germany’s and Austria’s lead country representatives to the Task, participated in a joint workshop convened by the IEA Advanced Motor Fuels (AMF) Technology Collaboration Program (TCP) and the IEA Combustion TCP 6th November in Montreux, Switzerland. Both already participated in the IEA AMF TCP. Their attending this workshop helps Task 39 identify areas for future collaboration with these other transport-related IEA TCPs, which like Task 39 are interested in advancing efficient low emission propulsion systems and new concepts for more efficiently using advanced fuels in advanced engines. Specific collaborations are still to be defined however there is mutual interest in the advanced fuels for advanced engines arena to maximize the potential of biofuels (and also of lower carbon renewable fuels of non-biological origin) to decarbonize transport. Next steps include preparing a “map” on overlapping topics of IEA AMF, IEA Combustion and IEA Bioenergy within the “magic triangle” of system costs, CO₂/GHG and pollutants, developing on joint webinars and dedicated working groups ([Read more](#)).

In closing, we are grateful to Henning Jørgensen and Sune Tjalfe Thomsen, Denmark’s representatives to the Task, for co-authoring this newsletter’s feature article on biofuels-related developments in Denmark.

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 Denmark: Status, Advances and Challenges

Sune Tjalfe Thomsen and Henning Jørgensen, University of Copenhagen

1. Status of transportation biofuel industry in Denmark

In Denmark, a considerable part of the total energy demand is derived from renewable sources. In 2017, 26% of Denmark's primary energy production of 658 PJ was from renewable energies (54% from biomass, 31% from wind and 3% from solar). Within electricity production, 64% was from renewable energies. Wind power was the largest source of renewable electricity, accounting for 43% of all electricity production in 2017, with biomass contributing 17%.

In 2017, the transport sector accounted for 34% of Denmark's total energy use. A total of 162 PJ was used for road transport, equivalent to roughly 4 million tonnes of gasoline/diesel fuels. Of this, 74% was used for passenger transport, with diesel accounting for 65% of the fuel. Aviation consumed 42 PJ, corresponding to almost 1 million tonnes of jet fuel. Domestic rail and sea transport used another 4.8 PJ and 6.2 PJ, respectively. The total energy use for road, rail and sea transport has been fairly stable over the last 10 years, whereas energy use for aviation has increased 10-15%.

The transport sector is one of the largest contributors to Denmark's greenhouse gas (GHG) emissions. In 2016, transport accounted for 26% of Denmark's total GHG emissions of 50.5 million tonnes of CO₂eq. Despite relatively stable emissions from transport over the past 15 years, transport's share of total emissions has been gradually increasing (from 21% in 2005). This is due to more quickly decreasing GHG emissions from primarily the energy sector (heat and power) where fossil resources have and continue to be replaced by renewables (i.e., primarily wind and biomass). (Energistatistik 2017)

Denmark, being a member of the EU, follows the EU directive on use of renewables in the transportation sector. Since 2012, the overall share of biofuels in the Danish transport sector has been 5.75%, with Denmark blending 5% of ethanol into gasoline (E5) and 7% of biodiesel (FAME) into diesel (B7). In Denmark, there has generally been opposition to conventional food crop-based (1G) biofuels, particularly to the use of palm oil for biodiesel production. As a consequence, the use of palm oil has gradually decreased and, since 2018, Danish biodiesel has used as feedstock either rapeseed oil or waste fat (slaughterhouse waste), which is also eligible for double counting (Figure 1).

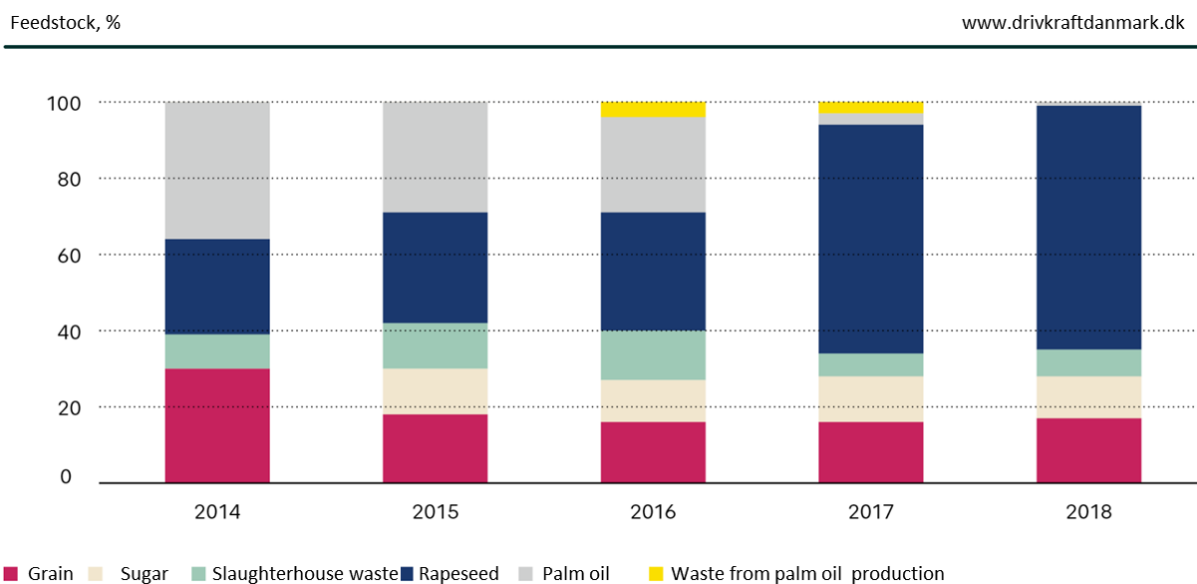


Figure 1: Share of different feedstocks used for biofuels in Denmark (source: DrivkraftDanmark)

Denmark currently has no domestic ethanol production, meaning that imports are used to supply the annual consumption of nearly 86,000 m³. There is domestic production of biodiesel (FAME), which in 2018 covered roughly 20% (44,000 m³) of Denmark’s annual total biodiesel consumption of 220,000 m³ (Figure 2). There are two operating biodiesel plants in the country. Emmelev Mølle (www.emmelev.dk) started operation in 2001 based on rapeseed oil feedstock, with an annual production capacity of around 180,000 m³, of which a large share is exported. Daka ecoMotion (www.dakaecomotion.dk) started production in 2008 based on animal waste fat and oils, which according to the EU legislation are eligible for double counting. Their annual production capacity is 55,000 m³. Use of compressed natural gas (CNG), e.g., from upgraded biogas, for transport is very limited (2 mio m³ of biogas in 2018) and has mainly been in fleets e.g. public busses, etc.

Electric passenger cars (EV) are gradually increasing their market share. By end of 2018, EVs accounted for 0.4% of Denmark’s passenger car fleet. In the first quarter of 2019, EVs or hybrid cars accounted for less than 4% of total car sales.

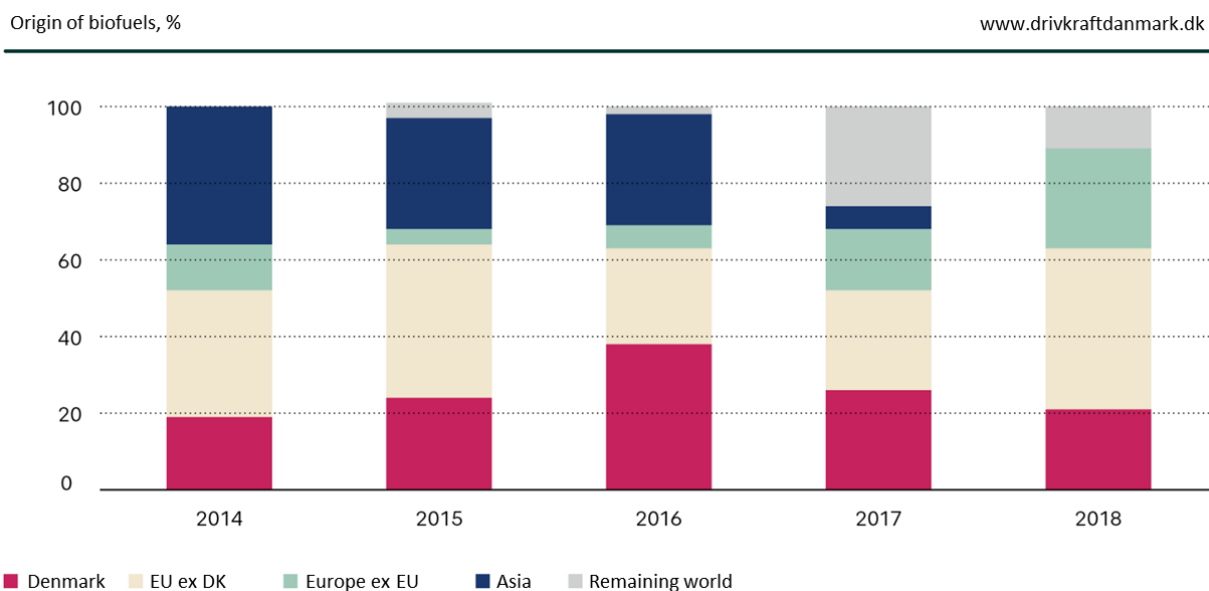


Figure 2: Origin of biofuels used in Denmark (source: DrivkraftDanmark)

2. Policies driving the production and consumption of biofuels in Denmark

The main drivers for biofuels policies in Denmark are to contribute to Danish and European transport and climate security. As an EU member state, Danish legislation and policies regarding climate, energy and renewable energy to a significant extent reflect overall EU regulation and directives.

Until 2020, Danish legislation regarding the use of biofuels is based on the EU renewable energy directive RED 2009/28/EF. Although in 2006 the company Statoil (now Circle K) on a voluntary basis introduced 5% conventional ethanol in gasoline and subsequently together with Inbicon offered a 5% blend of cellulosic (2G) ethanol, official blending mandates for ethanol and biodiesel were not introduced until 2010. Since 2012, blending of E5 and B7 has enabled Denmark to reach its minimum overall target level of 5.75% renewables in transport as mandated in the EU directive.

The EU directive (EU 2009/28/EF) was set to cover the period 2010 to 2020 and specifies 10% renewables use in the transport sector as a final target for 2020. Alongside this directive, the EU Fuel Quality Directive (EU 2009/30/EF) targets reducing cradle-to-grave GHG emissions per energy unit by 6% in 2020 (compared to 2010). Increasing the current overall blending level of 5.75% to 8.15% would allow Denmark to meet the overall target of 10% renewable energy in

its transport sector when also including electrical vehicles and electricity used for rail transport. One option is to introduce E10, however this fuel standard still awaits official approval with less than one month before it would need to be implemented. Another option is to increase the use of renewable diesel (HVO), which can be done without changing fuel standards or legislation.

As of October 2019, the Danish government has proposed a new law to increase the average mandatory blending level to 7.6%. This law is expected to be passed in the parliament later this December. This means that fuel distributors/oil companies have to ensure that a minimum of 7.6% of their annual sales are biofuels (measured by energy content). All fuels have to contain a minimum of 1% biofuels. In addition, there will be a minimum requirement of 0.9% advanced biofuels on annual basis. Advanced biofuels are defined according to EU2015/1513 appendix IX part A (e.g., biofuels produced from cellulosic materials, algae, organic waste fractions or waste cooking oil). The oil distributors expect to introduce E10 beginning in 2020, but as it stands now, the new blending target will only be enforced in 2020. From 2021, the blending target will be reduced back to 5.75%. It is likely that gas stations will continue to offer E10, but the biodiesel blend level will be reduced to B5. From many sides, including industry, this last-minute temporarily solution is being met with criticism, e.g., the distributors have to offer a new fuel standard for only temporarily use. The argument for not continuing with the higher blending mandate is that the government does not find that blending biofuels offers enough GHG saving relative to the costs (i.e., loss of CO₂ tax from fossil fuel) and is thus not a long-term solution. However, this complicates the current discussion of how to reduce transport-related GHG emissions in the short-term. These types of short-term policies and last-minute decisions provide a good example of how difficult it is to ensure stable framework conditions for the biofuels industry.

From 2020, the new EU renewables directive (RED II) will replace the old directive (For more details see [Task 39's Newsletter issue #50](#)). In short, the new directive has a minimum final goal of 14% of renewable energy in transport by 2030. From 2022, 0.2% of this has to come from advanced biofuels, increasing to 1% in 2025 and 3.5% in 2030. A maximum of 7% can be from conventional food-based feedstocks (1G). The Danish position remains unclear. There is a lot of focus on electrification of the transport sector, however specific plans await the government announcing its climate act, expected to occur by end of 2019.

In Denmark, there is a strong focus on sustainability aspects of biofuels, especially traditional (1G) biofuels as exemplified by the absence of palm oil derived biodiesel (Figure 1) in the Danish market. The food versus fuel issue has and continues to influence the discussion of 1G bioethanol. As a consequence, biofuels such as 1G bioethanol have never been politically popular or economically supported in Denmark. The only policy/economic difference between biofuels and fossil fuels is the absence of a CO₂ tax of EUR 0.06 per liter (note: the current gasoline price in Denmark is around EUR 1.6 per liter). Partly because of this policy, dedicated 1G bioethanol production has never been established in Denmark, despite some attempts in the period 2000-2010 based on using grain as feedstock.

Because liquid biofuels are only considered a short-term solution, with medium to long-term solutions focusing on electrification of passenger transport, only for heavy duty road transport as well as maritime shipping and aviation are advanced biofuels considered a cost-effective solution. This policy is also due to Denmark placing a high value on the use of biomass for combined heat and power (CHP) production, as CHP production is already widely implemented in the Danish energy supply and provides a more cost-effective way to use biomass resources. Despite substantial ongoing research and development efforts in the area of producing cellulosic ethanol from agricultural residues, commercial production of advanced bioethanol in Denmark has not yet been successfully established.

In 2018, the Danish Parliament passed a new energy act for 2020-2030 that set an overall target of 55% renewable energy by 2030. This energy act mainly addressed energy supplied in the form of electricity or heat, e.g., by dictating expansion of wind power and increasing energy efficiency in buildings and industries. The transport sector was only weakly mentioned and no direct measures were included for lowering energy consumption or introducing more renewable energy into the transport sector. After an election in June 2019, the government shifted from a Conservative/Liberal coalition to a Social Democratic party-led government supported by a left-wing coalition. Climate

was a large topic in the campaigns. The new government has committed to a very ambitious target for reducing GHG emissions in 2030 by 70% (as compared to 1990 levels). The 2050 goal is to be 100% GHG neutral. The government has not yet proposed an actual climate act and a detailed description of how Denmark is going to meet these ambitious targets is in preparation. A climate act setting the overall framework conditions is expected to be issued Christmas 2019.

In relation to the transport sector, electrification is overall the main driver, particularly for light duty vehicles. A ban on new combustion engine-based cars after 2030 was suggested by the previous government, but not made into law. An ambitious target for electric vehicles (EVs) has also been proposed, which would require replacing almost 30% of the current car fleets in 10 years. These goals reflect the fact that the Danish electricity supply is already close to 70% based on renewables (wind, solar and biomass). For 2030, the target is that current wind power capacity (5500 MW) will double and photovoltaic capacity will increase almost five fold to reach 4900 MW. Due to this large expansion of renewable electricity production, Danish production of electrofuels has been mentioned as a possible solution for heavy duty transport (i.e., road freight, shipping and aviation).

To support its ambitious climate goals, for 2020 the government has allocated EUR 200 million for research and development in the area of climate, sustainable transport solutions, etc. Details on how this money will be allocated are yet to be announced. In previous years, annual public support for energy research, development and deployment has been on the order of EUR 70-100 million.

3. Advances in biofuels technologies including a historical perspective on Danish development efforts

3.1 Bioethanol

Denmark has historically been leading in developing technologies for advanced bioethanol production from lignocellulosic resources, primarily focusing on cellulosic ethanol production from agricultural residues such as straw. The company Inbicon, a subsidiary of DONG Energy (now Ørsted), started developing their hydrothermal pretreatment technology for lignocellulose deconstruction around 2002. From 2003, they were operating their first pilot scale pretreatment unit with a capacity of 50 kg biomass per h input (dry matter basis). A key element in their technology is the “free fall mixing” principle, which enables high solids enzymatic liquefaction and hydrolysis (Jørgensen et al., 2007). In 2009, they inaugurated a demonstration plant in Kalundborg based on these technologies. The Kalundborg demo plant had a capacity of 4 tonnes per hour of biomass (dry matter basis, mainly straw) and an annual nominal ethanol production capacity of 5.4 million L (Larsen et al., 2012). This plant was operated until around 2014, when the company announced it had successfully demonstrated all of the technologies in continuous operation and reached its performance targets. They therefore considered the technology to be proven and ready to commercialize. During the time the plant was in use, it was refitted/rebuilt in order to demonstrate new concepts, e.g. the possibility to recycle enzymes and perform C5 fermentation using a new genetically engineered yeast strain from DSM (Haven et al., 2015). After closing down the plant, in 2015 Inbicon halted its research in the ethanol area.

In the same period as Inbicon was developing their technology, another Danish company, BioGasol, was developing an alternative process for cellulosic ethanol production (www.biogasol.dk). This company was formed in 2006 as a spin-off from the Technical University of Denmark, where a small pilot scale plant (Maxifuel) had been operated for some years. BioGasol’s concept is built on several key technologies, including a pretreatment process based on the unique Carbofrac™ reactor system and a Pentoferm™ fermentation platform based on a thermophilic anaerobic bacteria capable of C5 and C6 sugar fermentation. After upscaling, the Carbofrac™ pretreatment technology was demonstrated at a 1 tonne per hour scale and the Pentoferm™ fermentation technology at the cubic meter scale. In 2013, the company announced the first sale of a Carbofrac™ 400 reactor (400 kg/h) to Sweetwater Energy in the USA. The company later faced economic difficulties and in 2016 stopped developing their technology. The UK based company Nova Pangea subsequently has acquired rights to some of Biogasol’s technology.

Founded in 2007, the company Terranol A/S (www.terranol.com) develops yeasts to be applied for cellulosic (2G) ethanol production. By applying proprietary technologies, Terranol has developed industrial yeasts that can efficiently produce ethanol from all C6 sugars and also the C5 sugar xylose at a rate that is among the best obtained today.

Novozymes, the world's largest producer of industrial enzymes, is headquartered and has production facilities in Denmark, and has been one of the companies leading the development of enzyme solutions for both 1G and 2G bioethanol production, e.g., the cellulase mix Cellic® CTec3. They have been actively engaged in numerous Danish, European and international research projects within the area. The company has also invested in projects/companies upscaling and commercializing 2G bioethanol, e.g., it was together with M&G involved in the joint venture company Beta Renewables, which resulted in pioneering the world's first commercial scale 2G bioethanol plant in Crescentino, Italy. Besides enzymes, Novozymes now also offers yeast solutions for ethanol production (e.g., Innova® Lift).

The Maabjerg Bioenergy Concept was a project started in 2011-12 to upscale the Inbicon technology to commercial scale. This project involved a consortium comprising a local utility company, DONG Energy and Novozymes. In 2014, this consortium was granted funding (39 million EUR) from the European NIR fund, but the project has not yet been realized due to a variety of factors, including a lack of policy drivers, no mandatory blending requirement for advanced ethanol, in addition to difficulties securing financing/loan guarantees. Despite these challenges, there are still ongoing efforts to try to realize this project.

3.2 Maersk and lignin ethanol oils (LEO) for marine fuel

Unlike ethanol for road transport, dedicated biofuels for maritime shipping have only recently become a research focus. Global shipping accounts for 2-3% of total CO₂ emissions, and this is projected to grow with increased international trade. The Danish company Maersk – the world's largest shipping company – recently announced new ambitious goals and measures to reduce its carbon footprint. In 2018, they established a goal to be CO₂ neutral by 2050. According to Maersk, to achieve this goal will require that by 2030 there are affordable ships available that do not emit CO₂. Maersk hopes to push for this development within the industry. After conducting a study with Lloyd's Register, Maersk believes that alternative fuels like alcohols provide a more viable option than electric power in helping the cargo shipping industry become carbon neutral. The company's internal research suggests that ship owners should focus on developing alcohols, biomethane and ammonia as fuels for future marine transport (MAERSK, 2019a). Further, new technologies should be developed to replace current petroleum-dependent solutions, which applies to everything from fuel production to engine manufacture (MAERSK, 2019a). This joint study between Lloyd's Register and Maersk indicates that ship owners must invest for fuel flexibility. They also find that this transition presents more of an operating expenditure challenge rather than capital expenditure challenge (MAERSK, 2019a). Regarding alcohols (ethanol & methanol), existing solutions for handling the lower flash points and for burning alcohols are well proven, and ethanol and methanol are also fully mixable in a vessel's bunker tanks, creating fuel bunkering flexibility.

On the fuel side, the most interesting new announcement regards lignin ethanol oil (LEO), where Maersk and fellow shipping company Wallenius Wilhelmsen have teamed up with the University of Copenhagen and major customers including BMW Group, H&M Group, Levi Strauss & Co. and Marks & Spencer to form the LEO Coalition. This coalition will explore the environmental and commercial viability of using LEO fuel for shipping (MAERSK, 2019b). The initial work on LEO started back in 2012 with a large Danish project lead by the University of Copenhagen and including partners from Maersk, Novozymes and Inbicon. The University of Copenhagen is currently running laboratory-scale development of this new potential marine fuel. According to Maersk, the project aims to move into phase II – testing the fuel on actual vessel engines – as soon as possible; Figure 3 shows the engine of the containership *Soroë* Maersk that Maersk has used to test alternative marine fuels. As LEO is produced from lignin and ethanol, further development of allied biorefinery technologies also will be essential to secure a long-term supply.

3.3 Hydrothermal liquefaction (HTL)

Research in the area of producing bio-oil by HTL technologies and upgrading this oil into various drop-in biofuels is ongoing both at Aalborg University (www.aau.dk) and Aarhus University (www.au.dk). Both universities operate HTL processes at pilot scale. Aalborg University has for many years worked closely with the Danish-Canadian company Steeper Energy on developing HTL technology for marine fuels. In 2017, Steeper Energy announced they were

partnering with Silva Green Fuel, a Norwegian-Swedish joint venture, to construct a EUR 50.6 M industrial scale demonstration plant at a former pulp mill located in Tofte, Norway to be based on Steeper Energy's Hydrofaction™ HTL technology (Steeper Energy). Aalborg University is currently the coordinator of the HyFlexFuel project, a large EU project aimed at advancing HTL technology and improving the upgrading of HTL oils to yield desired fuel fractions (i.e., gasoline, diesel and jet fuel blendstocks) (www.hyflexfuel.eu).

3.4 Other technologies

The Danish company Haldor Topsøe (<https://www.topsoe.com/>) is a leading producer of catalysts for the petrochemical industry. Within the area of biofuels, they offer a range of technologies based on catalytic upgrading of syngas to produce drop-in fuels. The Topsoe Improved Gasoline Synthesis (TIGAS™) technology, originally developed in conjunction with coal gasification to produce liquid fuel, has been successfully demonstrated with biomass. In Sweden, Haldor Topsøe has also been involved in demonstration scale projects on dimethyl ether (DME) production from methanol produced from gasified biomass. Haldor Topsøe also has technology (HydroFlex™) for hydro-treating vegetable oils to produce HVO and drop-in biofuels. This technology has been selected for the first European plant being designed to produce Sustainable Aviation Fuel (SAF). This facility is being constructed in Delfzijl, the Netherlands, by SkyNRG with KLM as a strategic partner. The plant will have an annual production capacity of 100,000 tonnes. (Haldor Topsøe)

Research on so-called electrofuels or Power-to-X fuels is gaining momentum in Denmark. Due to the large share of wind power in the Danish electricity grid, periods of more than 100% coverage of electricity demand by wind power are becoming more frequent. Although surplus electricity normally is exported to neighboring countries, the price is usually very low, or even negative. With a large projected expansion of wind power, options to store or utilize surplus electricity are therefore of great interest. Several research projects are ongoing and one demonstration plant for power-to-methane (1200 m³ per day) is operating in Copenhagen at the BIOFOS wastewater treatment plant based on upgrading of CO₂ in biogas. Other research projects include 'The Villum Center for the Science of Sustainable Fuels and Chemicals' at the Technical University of Denmark (www.v-sustain.dtu.dk) and a biogas upgrading pilot plant at Aarhus University involving Haldor Topsøe.

Another cross-over technology combining biomass gasification with use of excess wind power is the SYNFUEL project lead by the Technical University of Denmark. Electricity is used in Solid Oxide Electrolysis Cells (SOEC), developed Haldor Topsøe, to produce hydrogen, which is then reacted with syngas produced by a Pyroneer gasifier (technology originally developed by DONG Energy/Ørsted) to yield methanol. (TUD)

4. Challenges to further production and use of biofuels in Denmark

Despite many years of research on ethanol production from lignocellulosic biomass and demonstrating the upscaling of the Inbicon technologies, it seems unlikely that dedicated commercial ethanol production will happen in Denmark. Politically, the use of biomass for production of liquid biofuels has never been endorsed widely, and for passenger cars electrification is seen as the preferred technology solution. However, current policy puts a large focus on expanding electricity production from wind and solar and in a longer perspective the aim is to dramatically reduce the use of biomass for heat and power. This could potentially open up opportunities for other biorefinery uses of the biomass. The research and development done in relation to production of ethanol from lignocellulosic biomass has resulted in key technologies for producing sugars from biomass. These technologies could be transferred to other biorefinery concepts for production of chemicals. Less use of biomass for heat and power could also open up opportunities for technologies such as HTL with the potential to produce drop-in fuels for heavy duty transport (road, marine or aviation). LEO is an interesting solution for the marine sector and Denmark is playing an important role in developing this technology. However, Danish domestic production is less likely as Denmark is not a large strategic hub. Bunkering of large ocean going ships is primarily done at the major ports around the world. Therefore, the production of lignocellulose-based fuels, e.g., LEO, would most logistically be placed close to major ports.

5. Conclusions

Denmark has for many years been in the forefront of renewable energy research. In the area of liquid transportation fuels, this has particularly been on the basis of lignocellulosic biomass. Although cellulosic ethanol is not a focus area anymore, the developed technologies can potentially be used in other biorefinery concepts. Currently, several research and demonstrations projects are working on biomass-based solutions for the heavy duty transport sector, including marine and aviation.

6. Acknowledgements

The Danish participation in IEA Bioenergy Task 39 is supported by the Danish Energy Agency, EUDP contract 64018-0598.

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In the News

Reports and Research

- August – The U.S. Department of Energy’s BioEnergy Technologies Office issued the report, “Waste-to-Energy from Municipal Solid Wastes.” This report assesses potential R&D activities to improve the economic viability of municipal solid waste-to-energy and waste-to-fuel facilities in the U.S. ([Read more](#)).
- October – The Deutsche Post DHL Group published a whitepaper on “Sustainable Fuels for Logistics.” This white paper offers an overview of the current discussion on sustainable fuels and identifies the types of fuels and technologies that are needed to achieve climate neutral logistics ([Read more](#)).
- October - The International Energy Agency (IEA) released its “Renewables 2019” report. This report provides a market analysis and forecast from 2019 to 2024 on renewable energy technologies, highlighting global trends and likely future developments for renewable energy in the electricity, heat and transport sectors ([Read more](#)).
- November - The MIT Energy Initiative published the “Insights into Future Mobility” report documenting the results of a three-year study to examine how the complex interactions between advanced vehicle drivetrain options, alternative fuels, refueling infrastructure, consumer choice, vehicle automation, and government policy may shape the future for personal mobility ([Read more](#)).
- November - Argonne National Laboratory has expanded and updated its GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model. The GREET® 2019 model is developed by Argonne with support from the U.S. Department of Energy (DOE). GREET is a life-cycle analysis (LCA) tool structured to systematically examine the energy and environmental effects of a wide variety of transportation fuels and vehicle technologies in major transportation sectors (i.e., road, air, marine, and rail) ([Read more](#)).
- November - The IEA released its World Energy Outlook 2019 report. The World Energy Outlook report series offers strategic insights on the future of energy and energy-related emissions, providing detailed scenarios that map out the consequences of different energy policy and investment choices. This year's edition updates the outlooks for all fuels, technologies and regions based on the latest market data, policy initiatives and cost trends ([Read more](#)).
- November - In Australia, the government has announced the development of a new roadmap to enhance the growth of Australia’s bioenergy sector and identify the role bioenergy can play in Australia’s future energy mix. Minister Taylor has requested the Australian Renewable Energy Agency (ARENA) to develop the roadmap to ensure that bioenergy has the scope to expand as an energy source in Australia ([Read more](#)).
- November - Germany’s Federal Office for Agriculture and Food (BLE) published its 8th annual report on biomass fuels and biofuels in Germany including the flow of goods to other countries. The Evaluation and Progress Report 2018 intends to inform both the interested public and experts on the development and progress of biofuels brought into circulation in Germany ([Read more](#)).

Policy and Regulatory Developments

- September - Canada’s national clean fuels associations forecast greenhouse gas (GHG) emissions reductions of over 50 million metric tons per year by 2030 in Canada through greater production and use of renewable energy. These associations comprise Advanced Biofuels Canada (ABFC), the Canadian Biogas Association (CBA), the Canadian Gas Association (CGA), Electric Mobility Canada (EMC) and the Wood Pellet Association of Canada (WPAC), which together represent a majority of Canada’s primary clean fuel industries ([Read more](#)).
- September - Allegations of unsustainable palm oil being used for biodiesel production by mis-categorizing it as used cooking oil (UCO) have prompted both the UK and the Netherlands to launch investigations to get to the bottom of the controversy. If it ends up being true, the Netherlands says it could force the end of double counting of UCO-

based biodiesel for renewable energy blending mandates in transport under the EU's RED Directive II. The investigation in the Netherlands is going on alongside a fraud investigation into a Dutch biofuel company ([Read more](#)).

- September - Colorado has taken an initial step toward considering the establishment of a Low Carbon Fuel Standard (LCFS). Colorado's Energy Office issued a documented quote (DQ) on September 11 inviting bids from independent contractors to conduct an LCFS feasibility study ([Read more](#)).
- September - China is looking to scale back its ambitions for increasing ethanol production, which had been aiming to enable a 10% ethanol blend, given reduced corn availability. A lack of corn grain feedstock has been the main inhibitor to boosting ethanol production ([Read more](#)).
- October - The province of Quebec, Canada, released a draft policy for 10% ethanol blending by 2021 and 15% by 2025, with these levels falling to 9% and 13.5%, respectively, if the ethanol itself has at least 10% cellulosic content. The province used 470 million liters of ethanol in 2017 and the policy aims to double this. A 2% bio-based diesel mandate is also proposed for 2021, rising to 4% by 2025, compared to almost nothing in 2017 ([Read more](#)).
- October - Washington state's Puget Sound Clean Air Agency issued its Low Carbon Fuel Standard rule for consideration. This is the first economic region to attempt an LCFS, and this follows the failure of the state legislature to pass a climate bills package offered in the legislative session concluded earlier this year ([Read more](#)).
- October - The U.S. EPA recently approved a Renewable Fuel Standard fuel pathway filed on behalf of Texmark Chemicals Inc. and Neste US Inc. that will allow renewable diesel produced at Neste's biorefinery in Porvoo, Finland, to be shipped to Texmark's facility in Galena Park, Texas, for fractionation to produce renewable jet fuel and renewable diesel ([Read more](#)).
- November - The Thailand government is preparing to launch E20 in early 2020 in an effort to help boost its farming sector. Domestic ethanol production is based on both cassava and sugarcane molasses feedstocks. Policy already supports palm oil farmers through the implementation of 10% biodiesel blending. E20 and E85 are already available at fueling stations as well as two grades of E10 that are likely to be phased out ([Read more](#)).
- November - Brazil boosted its biodiesel blend level to 12% in March, having just raised it to 11% in September. The country has its eyes on achieving a blend level of 15% by 2023 but is also discussing higher targets. Tests are already underway to study the impacts of 20% and 30% biodiesel blend levels, similar to what Asian countries are implementing. Increasing the blend level to enable B15 will require 9.7 billion liters of biodiesel production compared to 6.69 billion liter this year. Including new plants under construction, total annual production capacity is projected to grow to around 12.6 billion liters ([Read more](#)).

Industry News

- August - In the UK, Crown Oil has invested GBP 4 million in HVO production so that it may offer this fuel as an option to its fleet customers for long-distance transport, agricultural operations or other uses in an effort to shift fuel demand towards fuels that have fewer negative impacts fuel on the environment ([Read more](#)).
- August - Lufthansa's Innovation Hub has launched a new sustainability platform, Compensaid, to enable airline passengers to offset their individual carbon footprint using Sustainable Aviation Fuel (SAF). The platform combines a tracking tool for all airline flights worldwide with a sustainability platform that makes it possible to offset a passenger's personal CO₂ emissions. Travellers receive a detailed evaluation of their entire travel history including flight distance, time and destinations, as well as the efficiency of the aircraft type, individual fuel consumption and the associated CO₂ emissions ([Read more](#)).
- September - In Texas, Valero Energy Corporation and Darling Ingredients Inc. are addressing the growing demand for renewable diesel in global, low-carbon markets by initiating an advanced engineering and development cost

review for a new plant in Port Arthur, Texas. The proposed facility would be designed to produce 400 million gallons of renewable diesel annually as well as 40 million gallons of renewable naphtha. The new plant would be owned and operated by Diamond Green Diesel Holdings LLC (“DGD”), the 50/50 joint venture between Valero and Darling ([Read more](#)).

- September - In Colorado, Gevo announced it secured the supply of 5 MW of renewable electricity from an affiliate of Juhl Energy for its Agri-Energy production plant in Luverne, MN. Wind turbine generated electricity will be wired directly to Agri-Energy, enabling it to claim the benefit of a lower carbon intensity score under the Low Carbon Fuel Standard (LCFS) ([Read more](#)).
- September - TechnipFMC and the Dutch company BTG-BTL based in Twente will design and build a production facility in Sweden where wood residues will be converted into bio-oil. This will be the first plant in the world where ‘green fuel’ will be produced and further processed in a refinery to produce fuels for motor vehicles. The plant will convert roughly 35,000 – 40,000 tons of dry wood residues into oil each year using a pyrolysis technology. The pyrolysis oil will then be processed in a refinery to produce advanced biofuels. Once completed, this facility will enable an equivalent of 15,000 family cars to be powered per year using pyrolysis-derived petrol ([Read more](#)).
- September - Delta Air Lines is looking into establishing a biofuels plant in Washington state that would use forest floor debris (lignocellulosic biomass) to produce fuel for its U.S. West Coast operations. The U.S. carrier is investing \$2 million to partner with Northwest Advanced Bio-Fuels to examine producing sustainable aviation fuel for its operations in Seattle, Portland, San Francisco and Los Angeles ([Read more](#)).
- September - St1 Nordic Oy has licensed UOP’s Ecofining™ renewable fuels technology and intends to use this technology to produce 4,000 barrels per day of diesel and jet fuel integrated with its refinery complex in Gothenburg, Sweden. Basic engineering design for this project is already completed ([Read more](#)).
- September - Travelers flying with SAS can now voluntarily choose to buy biofuel and help to reduce climate-affecting CO₂ emissions by up to 80%. The new non-profit service aims to pioneer a large-scale and competitive market for biofuels within aviation, in line with SAS' sustainability strategy ([Read more](#)).
- September - Praj Americas is planning \$100 million plant in St. Martinville, USA to use sugar cane waste to make ethanol ([Read more](#)).
- September - IRENA forecasts zero emission deep sea vessels to be commercially viable by 2030 ([Read more](#)).
- October - In Finland, Neste and Lufthansa are strengthening their collaboration on the development of renewable solutions for aviation. As part of the collaboration, Lufthansa will use Neste’s sustainable aviation fuel, blended with fossil jet fuel, on flights departing from Frankfurt. The first batch of sustainable aviation fuel was delivered to Lufthansa earlier this year ([Read more](#)).
- October – Neste is expanding its presence in the Netherlands. The company has opened a new office in Hoofddorp in greater Amsterdam which will serve as the global hub for its growing Renewable Aviation business. Neste is now also offering Neste MY Renewable Diesel to its climate-conscious fleet customers ([Read more](#)).
- October - Neste is introducing Neste MY Renewable Diesel™, produced from 100% renewable raw materials, in Estonia beginning in October 2019. During the initial phase, private car owners and heavy-duty vehicle drivers can refuel with renewable diesel at one station in Tallinn. Neste MY Renewable Diesel is now available in all Baltic countries as well as in Finland, Sweden, and the U.S. states of California and Oregon ([Read more](#)).
- October - In Canada, Enerkem Inc. announced the closing of an additional C\$50 million equity investment from Suncor. As Canada’s leading integrated energy company, Suncor first participated in the ownership of Enerkem in

April 2019 as part of a C\$76.3 million equity financing alongside Enerkem's existing shareholders. With this new investment, Suncor becomes a significant, strategic shareholder of Enerkem ([Read more](#)).

- October - Sustainable Technology Corp. completed the acquisition of DuPont's technology assets for commercially producing ethanol from cellulosic biomass. Acquired assets include all associated intellectual property and patents including for process design and *Zymomonas mobilis* ethanologens ([Read more](#)).
- November - Gevo Inc. announced it has won a contract to supply the city of Seattle with renewable gasoline to fuel its fleets. The following day, the company announced it had signed a development agreement with Blocksize Capital for a technology to track the sustainability of renewable products ([Read more](#)).
- November - In the Netherlands, BTG and GoodFuels are preparing for a major investment in a new biorefinery to support shipping's increased demand for low carbon fuels. Biomass Technology Group (BTG) will set up a new company to convert crude pyrolysis oil into diesel fuel suitable for the shipping sector. This will be the first refinery in the world designed to produce advanced marine biofuel from pyrolysis oil ([Read more](#)).
- November - In Denmark, hydrogen infrastructure developer Everfuel Denmark A/S and A/S Dansk Shell (the Shell Refinery in Fredericia) and partners have entered into a strategic cooperation to supply green energy in the form of a hydrogen for the transport sector. The ambition is to be able to install the largest of its kind Power-to-X (P2X) hydrogen production plant in Fredericia to store and utilise excess wind power ([Read more](#)).
- November - POET-DSM to pause cellulosic ethanol production at the first US commercial-scale plant to make ethanol fuel from agriculture waste. Until market conditions improve, their production plant in Emmetsburg, Iowa, will cease commercial production and convert to an R&D facility ([Read more](#)).
- November - Biozin Holding AS announced it has entered into an agreement with Shell for financial support of their ongoing work to build a full-scale biocrude production facility in Åmli, Norway. The funding will support ongoing activities as part of the pre-engineering phase of the project ([Read more](#)).
- In the Netherlands, IKEA Transport & Logistics Services, the CMA CGM Group, and the GoodShipping Program have today announced the successful completion of their 2019 biofuel test program on CMA CGM vessels, following the positive trials of Heavy Fuel Oil-equivalent (HFO) Bio-Fuel Oil (GoodFuels BFO) during CMA CGM ALEXANDER VON HUMBOLDT's North Europe-Asia trip, which occurred in September and October 2019 ([Read more](#)).
- In Germany, the Federal Office for Agriculture and Food (BLE) published their 8th annual report on the evaluation and progress of biomass fuels and biofuels in Germany, and also on the flow of goods to other countries. This Evaluation and Progress Report intends to inform both the interested public and experts on the development and progress of biofuels brought into circulation in Germany ([Read more](#)).

Upcoming Meetings & Conferences

2020

January

- [8th ICIS Asian Oleochemicals Conference, January 15-16, Kuala Lumpur, Malaysia](#)
- [Fuels of the Future / 17th International Conference on Renewable Mobility, January 20-21, Berlin, Germany](#)

February

- [13th Annual International Biomass Conference and Expo, February 3-5, Nashville, USA](#)
- [11th International Conference on Biofuel and Bioenergy, February 19-20, Dubai, UAE](#)
- [15th World Convention on Waste Recycling and Reuse, February 20-21, Kuala Lumpur, Malaysia](#)

- [Lignofuels 2020, February 26-27, Helsinki, Finland](#)

March

- [Lignofuels Americas 2020, March 11-12, Omaha, USA](#)
- [International Conference on Biofuels & Renewable Energy, March 19-20, Berlin, Germany](#)
- [ABLC 2020, Advanced Bioeconomy Leadership Conference, March 25-27, Washington, DC](#)
- [11th International Conference on Biofuels and Bioenergy, March 23-24, London, UK](#)
- [Brazilian Bioenergy Science and Technology Conference, March 30-April 1, São Paulo, Brazil](#)

April

- [15th World Bioenergy Congress and Expo, April 20-21, Berlin, Germany](#)
- [Advances in Biomass, Biofuels and Bioenergy, April 23-24, New York, USA](#)
- [42nd Symposium on Biomaterials, Fuels and Chemicals, April 26-29, New Orleans, USA](#)
- [28th European Biomass Conference and Exhibition, April 27-30, Marseille, France](#)

IEA Bioenergy Task 39 Meetings

In 2020, IEA Bioenergy Task 39 will have its first business meeting in São Paulo, Brazil in conjunction with the [Brazilian Bioenergy Science and Technology Conference \(BBEST\)](#) being held March 30 - April 1, 2020. The BBEST meeting will be held jointly with the [Biofuture Platform](#), in which 20 countries are participating.

Please [contact us](#) for more detailed information about the Task's future business meetings.