Commercializing Conventional and Advanced Liquid Biofuels from Biomass

Task 39
IEA Bioenergy

Inside This Issue

From the Task

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IEA Bioenergy Task 39 is approaching the end of its 2016-2018 triennium. In this triennium, Task 39 continued its work to advance deployment of sustainable, lower carbon liquid biofuels for transport. Fourteen countries collaborated together to facilitate the commercialization of conventional and advanced liquid biofuels. In addition, Task 39 strengthened collaborations with other IEA Bioenergy Tasks (Tasks 33, 34, 36, 37, 40, 42 & 43 and new sustainability and deployment tasks being proposed for the 2019-2021 triennium) as well as with other groups such as the IEA Advanced Motor Fuels TCP, UN FAO and national programs. Task 39 also benefited from extensive industry involvement from companies at the forefront of biofuels development such as DSM, Borregaard, Licella, Novozymes, LanzaTech and the Renewable Energy Group.

During this period, Task 39 led several cooperative research projects assessing policy, markets and sustainable biofuel implementation issues and documented in reports and published on the Task's web site. In two cases, webinars were also organized to highlight new published reports and facilitate knowledge transfer and information dissemination between IEA Bioenergy members and other transport biofuels stakeholders. A summary of Task 39's significant achievements are provided below:

State of Technology Review - Algae Bioenergy: This study was a broad inter-task effort with contributions from IEA Bioenergy Executive Committee (ExCo) and Task members spanning 5 tasks (Tasks 34, 37, 38, 39 & 42) and 8 countries. It provided an international update on the status and prospects for using microalgae and macroalgae as feedstocks for producing biofuels and bioenergy products. The report's scope covered algae-based options for producing liquid and gaseous biofuels, and also algae-based bioenergy in the

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more general context of integrated biorefineries. A webinar on this study was held in late January 2017 and it was published in February 2017. Key findings include:

- High photosynthetic efficiency make algae a promising feedstock in the long term although near- to mid-term prospects for primary bioenergy/biofuels production are poor due to the cost of growing and harvesting (and concentrating/dewatering) algal biomass.
- Algal processing in a multi-product biorefinery context or integrated with wastewater treatment may enable economic bioenergy coproduction in the nearer term.
- To better identify and prioritize commercialization barriers that need to be overcome, greater data sharing and consensus/harmonization on analytical methods is urgently needed – from cultivation to product isolation and for related TEA and LCA modeling.

The full report can be downloaded here. A summary of the report is published in Algal Research.

Biofuels for the Marine Shipping Sector (2017-2018): This study assessed the current and developing marine fuel regulations and discussed marine fuel characteristics and the new CO_2 monitoring regime for ships. It also described biofuel production technologies and the outlook for development of marine biofuels. Finally, it provided a SWOT analysis of the potential and challenges for marine biofuels. This report was competed in September 2017 and a webinar about it was held in May 2018. Key findings include:

- *Marine biofuels are a large, nearer-term opportunity*, as sector sulfur emissions must be reduced, most biofuels have low sulfur levels, and many ship engines can use lower specification fuels compared to fuels used for aviation or road transport
  - Large market: Approximately 90% of international trade involves shipping
  - Simplified supply logistics: For international shipping, there are relatively few major marine ports to supply
  - *Significant potential for drop-in biofuels to replace part of the marine fuel mix*
  - *New multi-fuel heavy-duty marine engines* can also use alcohol biofuels (e.g., MeOH, EtOH)
- *Development remains challenging:* Testing requires: 1) very large volumes of biofuels; and 2) coordination among fuels producers, engine builders and ship owners.

The full report can be downloaded here.

Other reports the Task has completed or is close to finishing include:

- The Potential of Biofuels in China (2016) – Download here.
- Mobilizing Sustainable Bioenergy Supply Chains (2016) – Intertask report, carried out with cooperation between IEA Bioenergy Tasks 37, 38, 39, 40, 42, and 43. Download here.
- Drop-in Biofuels – report update (2018, pending). This study builds on the task's 2014 "The potential and challenges of drop-in biofuels" report.
- Yearly upate of the Bioenergy Task 39 large-scale demonstration plants at http://demoplants.bioenergy2020.eu/
- Survey of Advanced Biofuels for Advanced Engines – with IEA AMF (2018, pending)
- Comparison of LCA models - with Task 38 and also contributing to onging IEA Bioenergy intertask sustainability project (publication pending; under review by the journal of Renewable and Sustainable Energy Reviews)
- Implementation Agendas - international policies compare and contrast report (2018, pending)

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

As part its communication strategy, IEA Bioenergy Task 39 also organized the Task's twice per year business meetings and participated in several conferences and workshops held in conjunction with other conferences and seminars. The minutes of the business meetings are documented in past newsletters. These business meetings and affiliated conferences were:

- IEA Task 39 Business Meeting, Delft, the Netherlands, March 10, 2016 (in conjuction with ECO-BIO 2016)
- IEA Task 39 Business Meeting, Rotorua, New Zealand, November 8, 2016 (in conjuction with New Zealand's Advanced Biofuels Research Network (ABRN) Science Symposium and Bioenergy Australia 2016 Confererence)
- IEA Task 39 Business Meeting, Gothenburg, Sweden, May 15, 2017 (in conjuction with Sweden's 2017 Advanced Biofuels Conference)
- IEA Task 39 Business Meeting, Brussels, Belgium, Sept. 25-27, 2017 (in conjuction with 6th International Conference on Lignocellulosic Ethanol)
- Task meeting, Beijing, China, April 7-9, 2018 (in conjuction with Beijing University of Chemical Technology Bioenergy Symposium and China-Canada Joint Centre for Bioenergy Research and Innovation (CJCBERI) meeting)
- Task meeting, San Francisco, USA, November 5-6, 2018 (Pending, in conjunction with ABLC GLOBAL conference)

The Task's last business meeting of the 2016-2018 triennium will be 5-6 November 2018 in San Francisco, held in conjunction with the IEA Bioenergy Executive Committee end of triennium meeting (ExCo82)and also in conjuction with the Advanced Bioeconomy Leadership Conference GLOBAL ("ABLC GLOBAL") being held pthere 7-9 November. The first full day of the ABLC GLOBAL conference also constitutes IEA Bioenergy's end of triennium conference.

During this triennium, Task 39 has also continued its efforts to recruit additional countries to join the task. Former members invited to rejoin include Finland, Italy and Norway. Norway has confirmed its interest to rejoin in the next triennium to run 2019-2021. Other countries that are prospects to become new members of IEA Bioenergy and Task 39 in the next triennium include Chile, China, India, Indonesia, Malaysia, Mexico and Thailand. Economies in each of these countries are growing, with increased manufacturing and consumption leading to more freight transport (long-distance trucking, rail, shipping and aviation) and mounting concerns about how to decarbonize their economies, including their transport sectors, to meet their Paris Agreement commitments. Especially good interest has been demonstrated by India and Mexico, and contacts with China have also been greatly strengthened, and we remain optimistic that these countries will be able to join IEA Bioenergy and Task 39 during the next triennium.

In addition to commissioned reports, conference and workshop proceedings, Task 39 disseminated information through its periodic newsletters featuring country reports and hyperlinks to media stories and reports detailing the latest developments in industry and government policies pertaining to liquid biofuels. During the 2016-2018 triennium, 9 newsletters will be published (8 so far) and distributed to >3000 recipients with featuring articles on biofuel use and production and policies in Sweden, Australia, Austria, Korea, China, Africa, USA and Canada. These newsletters can be found at Task 39 website:
http://task39.ieabioenergy.com/newsletters/.

A summary of projects Task 39 proposes to undertake during the 2019-2021 triennium will be provided in the next issue of this newsletter planned for publication at the end of this year.

This Newsletter's feature articles describe biofuels-related developments in Canada.

As always, we appreciate your readership and are interested in any input or feedback on this newsletter. Please send us by email any ideas or suggestions for increasing its value.

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

Jim, Jack, and Mahmood

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

Mahmood Ebadian and Jack Saddler

1. Status of transportation biofuel industry in Canada

Similar to the rest of the world, transportation in Canada is fuelled almost exclusively by refined petroleum products derived from crude oil, including gasoline, diesel, aviation fuel and heavy fuel oil mainly used in marine vessels. Currently, over 96% of the transportation sector in Canada is fuelled by petroleum products, making this sector the second largest emitter of greenhouse gases (GHG) after the oil and gas sector. Figure 1 shows GHG emissions from the transport sector account for almost 23% of all GHG emissions in the country, with road transportation responsible for 80% of these emissions (Senate of Canada, 2017).

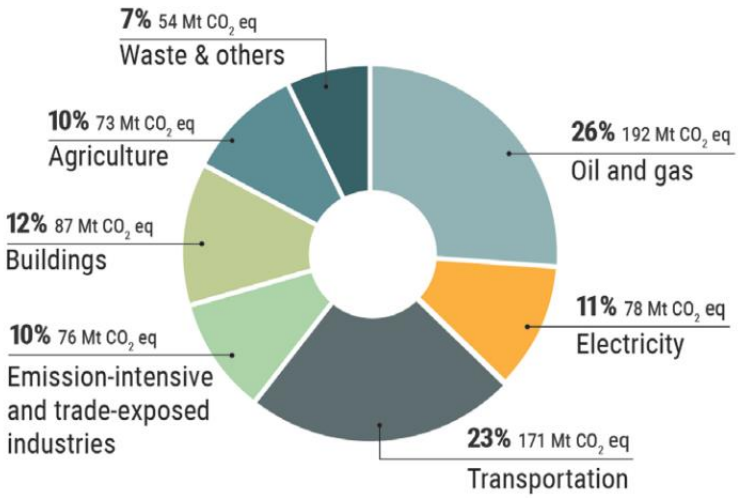

Figure 1. Canada's GHG emission breakdown, 2014. Total GHG emission was 731 million tonnes of CO_2eq with 23% contribution from the transportation sector (Source: Senate of Canada, 2017).

There are several alternatives to reduce the carbon intensity of the transportation sector including improving vehicle fuel efficiency through regulated fuel efficiency standards, increasing the number of alternatively fuelled vehicles such as electric and CNG/LNG vehicles, improving transportation infrastructure and optimizing transport modes, and shifting away from petroleum-based to less carbon-intensive fuels such as biofuels.

Conventional biofuels including bioethanol and biodiesel (conventional fatty acid methyl ester- FAME) and, to a small extent, natural gas, have been produced and used in Canada to decarbonize the road transportation sector. Both federal and provincial regulations are in place, known as renewable fuel mandates, which require minimum renewable fuel blending in all gasoline and diesel consumed in the country. In addition to renewable fuel mandates, other regulations are contributing to the decarbonization of the road transportation sector in Canada such as British Columbia's Low Carbon Fuel Requirements Regulation which requires the average lifecycle carbon intensity (CI) of fuel sold within the province to decline over time.

Figure 2 shows the consumption of transportation fuels in Canada from 2010 to 2016. As this figure shows, there was a steady increase in the consumption of ethanol over this period. The volume of ethanol consumed annually increased from about 1,700 million liters in 2010 to 2,800 million liters in 2015. The volume of biodiesel consumed annually also increased over the same period from about 110 million liters in 2010 to 470 million liters in 2015. Hydrogenation derived renewable diesel (HDRD) is also blended into diesel- though in smaller volumes. The amount of HDRD being

blended is estimated to have increased from 37 million liters in 2010 to 300 million liters in 2016 (Navius Research, 2018).

Since 2012, the United States (FAME biodiesel and, in recent years, HDRD) and Singapore (HDRD) have supplied between 85 and 100 percent of Canada's total imports of renewable fuels for diesel blending, with the European Union making up the difference. Figures 3 and 4 show Canada's consumption of ethanol and biodiesel and HDRD, respectively, indicating the feedstocks used and their associated avoided greenhouse gas (GHG) emissions. Biofuels consumption has avoided 24.9 million tonnes (Mt) of CO2e between 2010 and 2016. Annual avoided GHG emissions have grown from 1.8 Mt in 2010 to 4.1 Mt in 2016. Trends in biofuel carbon intensities in British Columbia indicate that biofuel production is becoming less emissions intensive (Navius Research, 2018).

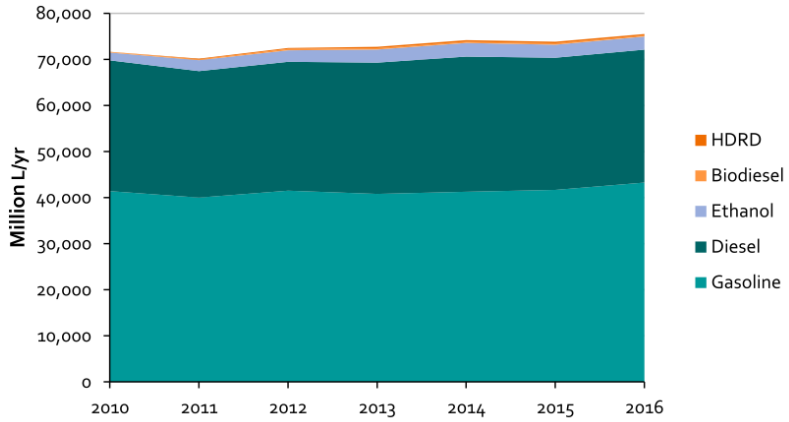

Figure 2. Fuel consumption in Canada, 2010-2016 (Navius Research, 2018)

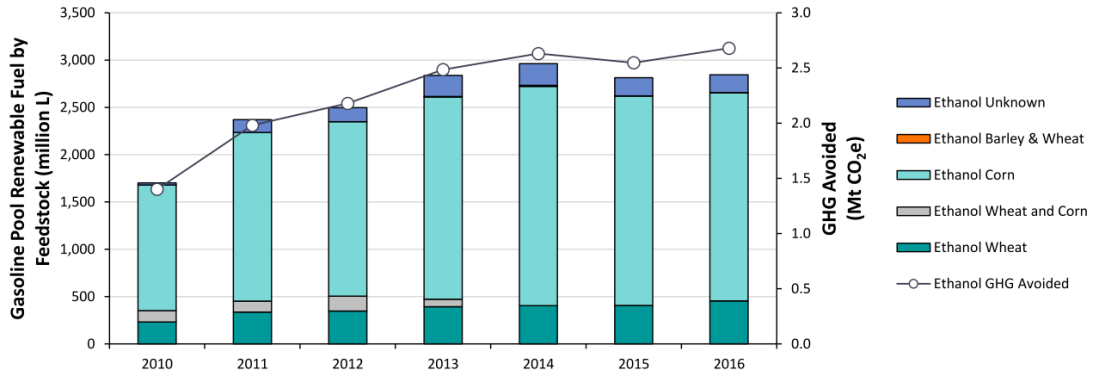

Figure 3. Consumption of ethanol in Canada by fuel type and feedstock, 2010-2016 (Navius Research, 2018)

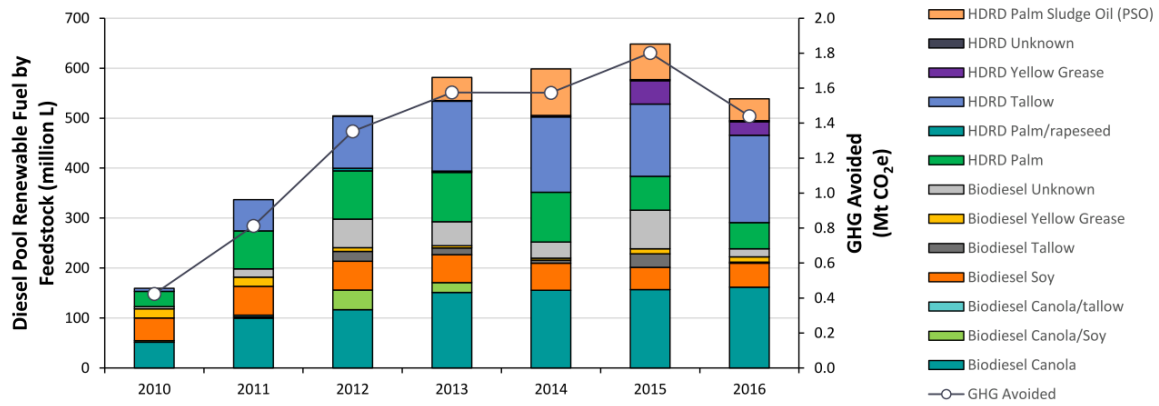

Figure 4. Consumption of biodiesel and HDRD in Canada by fuel type and feedstock, 2010-2016 (Navius Research, 2018).

In 2016, Canadian fuel ethanol utilization exceeded the federal use mandate (2,346 million liters of ethanol), at 2,843 million liters (6% ethanol in gasoline pool). However, for the purposes of the mandate, compliance units can be carried forward into a future compliance period, carried back for use in a previous compliance period, or cancelled if required to do so. Given the availability of suitable agricultural feedstocks and an interest to support rural development, a large portion of Canada's ethanol demand is met through domestic production. There are currently 11 operating ethanol plants in Canada with an estimated 1.7 billion liters of annual production capacity, which represents about 60% of total ethanol demand (Renewable Industries Canada and NRCan, 2018). On average, the United States supplies 98 percent of Canada's ethanol imports. As Canada imports ethanol to meet the federal blend mandate, there are generally no ethanol exports (USDA Foreign Agricultural Service, 2018).

Ethanol production has been nearly constant since 2011, with plants operating at or near full capacity. It is expected that fuel ethanol production will grow to 1,880 million liters in 2018 on limited capacity expansion projects and facilities continuing to operate at or near capacity (USDA Foreign Agricultural Service, 2018). Feedstock choice for ethanol plants has largely been driven by differences in geography and agronomy. Grain corn is the dominant feedstock, grown predominantly in Ontario, Quebec and Manitoba. Low protein, high starch wheat varieties are used in Alberta and Saskatchewan, and Manitoba uses both wheat and corn. There has been an increasing interest in developing corn varieties that can be grown in Western Canada. As more corn varieties are developed with lower heat unit requirements, it is expected that corn use for ethanol production will increase in Saskatchewan and perhaps Alberta (USDA Foreign Agricultural Service, 2018).

In 2016, 4.225 million metric tonnes of feedstocks were purchased by the ethanol industry. Between 2014 to 2016, two facilities switched feedstocks from wheat to corn in order to increase throughputs (the higher starch content in corn provides a greater ethanol yield) and improve production economics. It is estimated that in 2014, 78 percent of Canadian ethanol production was derived from corn and 22 percent from wheat. By 2016, corn contributed 81 percent of ethanol production, with wheat falling to 19 percent. It is anticipated that this corn/wheat split was similar in 2017 and will remain so in 2018 due to the location of plants in/around major corn producing regions (USDA Foreign Agricultural Service, 2018).

Canadian biodiesel production capacity has remained well below domestic demand since 2011, and in 2017 there was no commercial production of renewable diesel in Canada. In 2017, there were nine commercial FAME biodiesel production facilities in operation with total national biodiesel production capacity of 591 million liters per year. Most of Canada's biodiesel is produced from used cooking oil and animal fats, with the remainder being derived mainly from canola oil. The national market for biodiesel/renewable diesel will evolve further as provincial markets develop and implement clean fuel standards, a process already underway in some provinces. Based on the current federal mandate of 2% blending in diesel, about 600 million litres is required annually (USDA Foreign Agricultural Service, 2018).

In recent years, much of Canada's biodiesel production has been exported to the United States in response to U.S. biomass-based diesel tax support, Renewable Identification Number (RIN) support, and US Environmental Protection Agency (EPA) rule-making for obligated volumes under the U.S. Renewable Fuels Standard (RFS), which continues to grow U.S. demand for biodiesel. Canada imports sufficient volumes of FAME biodiesel and renewable diesel to meet Canadian blending requirements. In 2016, Canadian biodiesel exports increased 74 percent, reaching 464 million liters. In 2017, biodiesel exports fell from the record high 464 million liters to 350 million liters in response to reduced U.S. consumption. New US legislation excluding foreign-sourced biomass-based diesel from the tax credit would severely reduce, if not completely halt, Canadian exports of biodiesel to the United States. Such a policy shift would be expected to push more Canadian biodiesel into Canadian distribution channels and reduce Canadian imports of biodiesel (USDA Foreign Agricultural Service, 2018).

The economic impact of the construction phase of renewable fuels plants, at 2013 replacement cost prices, was assessed to include a total direct investment of $ 2.69 billion CAD and total net economic activity of $ 4.38 billion CAD.

The employment impact is the creation of 22,874 direct and indirect jobs during the respective construction periods (CRFA, 2013). A map of ethanol and biodiesel plants in Canada can be found here.

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

Canada has the world's third largest proven oil reserves, after Venezuela and Saudi Arabia, and is one of the top ten oil exporters in the world. Energy security is therefore not the driver for Canada's biofuel industry. The primary drivers for Canada's biofuel mandates are rural development, diversification of agricultural markets, and GHG emission reductions to fight climate change. GHG emission reduction and clean growth are now the primary drivers (USDA Foreign Agricultural Service, 2017).

Federal and provincial-level renewable fuels programs have continued to support conventional biofuels production and use across Canada. From 2006 through 2010, the provinces of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario established a blending requirement of 5 to 8.5% for ethanol in gasoline and 2 to 4% for renewable content in diesel. Federal use mandates followed thereafter, and, since December 2010, federal regulations have required fuel producers and importers to have an average ethanol content of at least 5% based on the volume of gasoline produced or imported. Since July 2011, federal regulations have required fuel producers and importers to have at least 2%, on average, renewable content based on the volume of diesel fuel and heating distillate oil that they produce or import. The current federal Renewable Fuels Regulations include a trading system and administrative, compliance, and enforcement provisions such as recordkeeping and reporting (ECCC, 2017).

Table 1 summarizes the percentage of ethanol and biodiesel to be blended with gasoline and diesel as mandated by provincial regulations in 2017. The details of these provincial regulations can be found at Navius (2016 and 2018) and USDA Foreign Agricultural Service (2018).

Table 1: 2017 Provincial Blend Mandates

Province	**Ethanol blend mandate for gasoline**	**Biodiesel blend mandate for diesel**	**Regulations**
British Columbia	5.0%	4.0%	The Renewable and Low Carbon Fuel Requirements Regulation
Alberta	5.0%	2.0%	Renewable Fuels Standard Regulation under the Climate Change and Emissions Management Act
Saskatchewan	7.5%	2.0%	The Ethanol Fuel Act and Ethanol Fuel (General) Regulations The Renewable Diesel Act
Manitoba	8.5%	2.0%	The Ethanol General Regulation Biodiesel Mandate for Diesel Fuel Regulation
Ontario	5.0%	4.0%	Ethanol General Regulation* Greener Diesel Regulation

***** This policy was approved to increase to 10% starting January 2020

In addition to Renewable Fuel Regulations, other federal and provincial initiatives are underway to decarbonize the transportation sector. The federal government has released a Pan-Canadian Framework on Clean Growth and Climate Change, which includes a federal carbon pricing framework. The Pan-Canadian Approach to Pricing Carbon Pollution was announced October 3, 2016. This pricing strategy would require all provinces and territories to have some form of carbon pricing plan in place by 2018. On January 1, 2019, the federal government will introduce its own carbon pricing system (the backstop) in provinces that do not design their own system or elements of the backstop in provinces where the system does not fully meet its criteria.

On December 13, 2017, the federal government released its Regulatory Framework on the Clean Fuel Standard (CFS), which describes how Canada will transition from volumetric-based requirements towards a carbon intensity-based

approach. Volumetric requirements under the current Renewable Fuels Regulations will remain in force until Environment and Climate Change Canada (ECCC) clarifies how Canada will transition to carbon intensity benchmarks. ECCC is the department within the Canadian government responsible for coordinating environmental policies and programs as well as for preserving and enhancing the natural environment and renewable resources. The most recent update on the CFS's timeline for developing regulations, including when the CFS will come into effect and the phased approach to be implemented for the regulated fuel streams, can be found here.

In a recent announcement, the federal government issued a nationwide challenge to Canadians to develop the cleanest, most affordable and sustainable aviation fuel to further reduce the carbon footprint of the aviation sector. The details of this program can be found here.

In addition to federal initiatives, current and underway provincial initiatives support the production and consumption of biofuels in Canada including British Columbia's Low Carbon Fuel Standard (BC-LCFS), Quebec's cap-and-trade carbon exchange program (excluding transport biofuels), British Columbia's carbon tax, Ontario's auction for carbon allowances, Alberta's levy of $20 CAD per ton on fossil fuel consumption in 2017, which has increased to $30 CAD per ton in 2018. Further details of British Columbia's Low Carbon Fuel Standard (BC-LCFS) are provided in the next article.

There are also a variety of fiscal incentives and investment subsidies that support or have supported the production and consumption of bioenergy and biofuels. Some of the largest incentive programs include:

- EcoEnergy for Biofuels had a $1.5 billion CAD budget over 9 years to boost Canada's production of biofuels. Administered by Natural Resources Canada, the ecoENERGY for Biofuels program ran from April 1, 2008 to March 31, 2017. This program provided incentive rates of up to $0.10 CAD/liter for renewable alternatives to gasoline and $0.26 CAD/L for renewable alternatives to diesel for the first three years, declining in the 6 years thereafter.

- The ecoAgriculture Biofuels Capital Initiative encouraged producer equity/ownership in biofuel facilities and was administered by Agriculture and Agri-Food Canada. The program helped fund projects that used agricultural feedstock to produce bio-fuels and required agricultural producer equity investments of 5% to meet eligibility requirements. This program was extended to March 31, 2013, but is now expired.

- The Program of Energy Research and Development (PERD) is a federal, interdepartmental program operated by Natural Resources Canada (NRCan). PERD funds research and development designed to ensure a sustainable energy future for Canada in the best interests of both its economy and environment.

- NRCan's Clean growth program is a federal program to advance emerging clean technologies toward commercial readiness so that natural resource operations can better reduce their impacts on air, land, and water, while enhancing competitiveness and creating jobs.

- Sustainable Development Technology Canada (SDTC) is a foundation created by the Government of Canada to support Canadian companies with the potential to become world leaders in their efforts to develop and demonstrate new environmental technologies that address climate change, clean air, clean water and clean soil. Since 2001, the Government of Canada has committed $1.364 billion CAD to SDTC.

There are also a number of new initiatives that support the development of clean technology, including bioproducts. In June 2017, the federal government announced a Low Carbon Economy Fund of $2 billion CAD to support projects that will generate clean growth and reduce GHG emissions towards meeting or exceeding commitments under the Paris Agreement. In addition, Canada is working with international partners through Mission Innovation. Canada is playing a leadership role in the implementation of Mission Innovation, as a member of the Steering Committee, as co-lead of the Joint Research & Capacity Building and Business and Investor Engagement subgroups, and through its

participation in the Information Sharing and Communications sub-group. Canada is also co-leading the Sustainable Biofuels Innovation Challenge - 16 countries looking to make progress towards implementing affordable, advanced biofuels for transportation and industrial applications. Finnaly, Canada is one of 20 countries participating in the Biofuture Platform, a government-led international effort to promote accelerated development of advanced low carbon fuels, biochemicals and biomaterials.

3. Advances in biofuels technologies

Canada has developed significant expertise in the development of technologies to convert non-food based feedstocks to ethanol. Examples of key players and current foci:

- Carbon Engineering – direct air capture of CO_2 and subsequent gasification to produce Fischer–Tropsch (FT) liquids
- Enerkem – gasification (municipal residues) and catalysis
- Ensyn – pyrolysis-based technology for renewable heating fuel and refining coprocessing to transport fuels
- Greenfield Global – integration of grain-based and cellulosic-based ethanol production
- Iogen – enzymatic hydrolysis (agricultural residues) and biogas-based fuels
- Forest Products Biotechnology and Bioenergy Research Group, University of British Columbia (UBC) – pretreatment of softwoods

Although Canada's production of biofuels using advanced technology platforms is limited, federal and provincial policy incentives favoring lower carbon intensity biofuels provide additional support to advanced biofuels production in Canada. Two Canadian firms have achieved, or will soon achieve, commercial-scale production. Enerkem makes cellulosic methanol and ethanol (which can be used as fuel or other industrial chemicals) from syngas by recycling carbon in non-recyclable municipal solid waste (MSW). In 2014, Enerkem launched the world's first full-scale MSW-to-biofuels and chemicals facility in Edmonton, Alberta. Enerkem's Edmonton plant started producing only methanol, but with the addition of a methanol-to-ethanol converter unit, the plant also began producing ethanol in 2017, with a current annual methanol-ethanol production capacity of 38 million liters. The Edmonton plant became the first ever MSW-to-cellulosic ethanol plant certified to meet renewable fuel obligations under the U.S. RFS and to generate RINs, having received U.S. EPA pathway approval in 2017. Also in 2017, its ethanol scored the lowest carbon intensity value ever issued by the British Columbia Ministry of Energy and Mines under BC's Renewable and Low Carbon Fuel Requirements Regulation (Source: Enerkem Website).

Ensyn Technologies Inc., established in 1991, began its focus on renewable fuels in 2005 with the commissioning of its 70 dry tons/day plant in Renfrew, Ontario, which was initially designed to produce renewable fuels and chemicals and then retooled in 2014 to focus on heating oil and fuel. Ensyn transforms woody biomass into pyrolysis oil that can be used as a biocrude feedstock and co-processed at refineries to produce lower carbon fuels and chemical feedstocks, used as a renewable fuel oil for heating and cooling, or to produce specialty chemicals. In 2014, Ensyn Corporation converted its production plant in Renfrew, Ontario to a dedicated fuels facility with a 12 million litre/year production capacity. Using Ensyn's patented RTP® pyrolysis technology, this plant has been supplying renewable heating fuel to clients in the Northeast US since 2014. Production capacity is also being used to develop and demonstrate refinery co-processing, and the use of Ensyn's pyrolysis oil as a renewable biocrude feedstock for petroleum refineries. In 2016, construction began on the Cote Nord Project at Port Cartier, Quebe, a 50/50 joint venture between Ensyn and Arbec Forest Products. This plant will have a capacity to transform forest residues using rapid thermochemical liquefaction into 40 million liters/year of biocrude. Project commissioning was scheduled to begin at the end of 2017, with product offtake focusing initially on heating markets in the northeastern U.S. and eastern Canada as well as a renewable feedstock for petroleum refinery coprocessing to produce lower carbon transport fuels (Source: Ensyn Website).

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

The existing and under-development federal and provincial policies and funding programs and strong intentions from different levels of governments have helped to reduce the carbon intensity of road transport in Canada. Both bioethanol and FAME biodiesel continue to play a role in decarbonizing transport and there is good evidence that the carbon intensity of such biofuels will continue to drop, with increasing blending levels of these biofuels resulting in enhanced decarbonization of light duty cars and trucks. However, the heavy duty freight and long distance transport

sector including aviation, marine, rail and trucking requires different types of biofuel, for example drop-in biofuels that can make better use of the existing petrochemical supply chain or the natural gas distribution system. The production of commercial volumes of advanced biofuels such as drop-in biofuels and renewable natural gas remains critical for federal and provincial governments to meet their carbon emission reduction goals.

Virtually all of the drop-in biofuels that have been produced and used globally to date have been derived via the so-called "conventional" or oleochemical route that that uses feedstocks such as Canola, Carinata, Palm, used cooking or other vegetable or animal derived oils and fats. The biggest challenges for this technology pathway are the cost, availability and perceived sustainability of energy-rich oleaginous feedstocks. For example, virgin vegetable oils are typically more expensive than diesel fuel itself, which makes it challenging to produce a replacement biodiesel fuel at a competitive price that enables the facility to be profitable.

Techno-economic challenges, including scale up to large commercial operations and high capital costs, have limited the production of advanced biofuels from lignocellulosic biomass such as corn stover, switchgrass and forest residues. Currently, many advanced biofuels are non-cost-competitive with petroleum fuels, partly due to the high capital and operating costs of pioneer facilities and partly because the price of fossil oil and gas remain relatively low. High specification fuels such as aviation biofuels are more costly to produce than fossil jet fuel, and will unlikely be cost-competitive for some time. Thus, policy incentives will be needed to support the development of new aviation fuels, which in the short- and mid-term offer the only significant means to decarbonize the aviation industry.

Currently, feedstock costs represent one of the biggest expenses in producing biofuels. Depending on the feedstock type, the conversion efficiency and the type of produced biofuel, feedstock can contribute between 60-80% of final fuel production cost (Landalv and Waldheim, 2017). Thus, establishing very efficient feedstock supply chains will be crucial to minimize biofuel production costs. Effective policy support will also play a role in mobilizing the development of new supply chains and supporting feedstock producers. For the case of cellulosic ethanol, key challenges have been noted with material handling of feedstocks, both in the collection of agricultural residues involving baling, storage and material handling while maintaining quality, and in smoothly feeding feedstock materials into production reactors, and these issues have limited its commercialization. Effective supply chains also need to be established for currently unutilized forest residues and perennial grasses.

5. Conclusions

Conventional biofuels have and will continue to play a role in reducing GHG emissions from Canada's transport sector and in complementing other strategies to decarbonize this sector such as vehicle electrification. The current federal and provincial policies have been effective to support production and use of biofuels over the last decade. However, additional government and international policies are required to increase biofuel use, especially for long-distance transport, which is needed to achieve emissions reductions targets. Regardless of the specific policy mechanism, e.g., a strengthened renewable fuel standard or a low-carbon fuel standard, future policies are needed to ensure supply and affordability of future fuel supplies to drive down greenhouse gas emissions and support sustainable low-carbon fuel production and use investments and innovation.

Canada has many of the key components needed to be a pioneer in the development of drop-in biofuels for long distance transport. Key among these is a favorable policy environment (e.g., carbon taxes, low carbon fuel standards) that can help bridge the price gap that exists between fossil-derived transportation fuels and lower-carbon-intensity drop-in transport fuels. However, equally important are the large amounts of potential feedstocks (both oleochemical and lignocellulosic biomass) that Canada produces in its substantial agricultural and forest sectors.

References

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British Columbia's Low-carbon Fuels Program

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Among provincial regulations, British Columbia's (BC) low-carbon fuels program has proven to be a successful program[1] to reduce the carbon intensity of the fuel transportation market in B.C. In 2010, B.C. enacted the *Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act*, also known as the B.C. Low Carbon Fuel Standard (BC-LCFS), fulfilling a commitment under the Pacific Coast Collaborative (PCC) to implement an LCFS along with California and the other members of the PCC.

The BC-LCFS requires lifecycle carbon intensity reductions increasing to a 10 percent reduction in transportation fuel carbon intensity by 2020. It functions similarly to the California LCFS by creating a system of credits and debits to assess the impacts of fuels in the market, and to provide flexibility for fuel suppliers to comply through a variety of pathways (see Figures 5 and 6 on next page). Fuel suppliers may reduce the carbon intensity of their fuels, locate and supply alternative fuels with lower carbon intensity, or purchase credits from other suppliers.

Effectively, this credit/debit system provides a cross-subsidy where high carbon intensity fuels are subsidizing the cost of low carbon intensity fuels. As a result, in 2017 when the carbon intensity targets required a 5 percent reduction, biofuel content was 7.3% ethanol in the gasoline pool. In the diesel pool, biofuel content was 5.4%, with 2.7% FAME biodiesel and 2.7% hydrogenation-derived renewable diesel (HDRD). As the targets continue to become more stringent, fuel suppliers are expected to continue increasing low carbon renewable content as part of their compliance strategy. B.C. imports most of its low carbon renewable fuel, primarily because the geography is not suitable for growing crops suitable for the production of ethanol and biodiesel and advanced biofuels such as HDRD.

[1] In concert with provincial biofuel mandates and carbon tax program

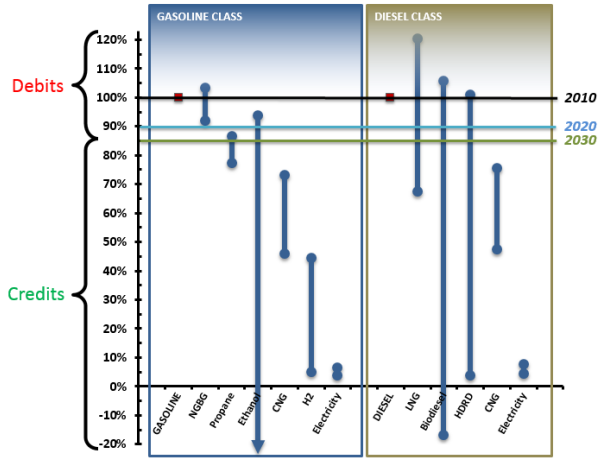

Figure 5. Relative carbon intensities of renewable and low carbon fuels in B.C. (B.C. Ministry of Energy, Mines and Petroleum Resources, 2018)

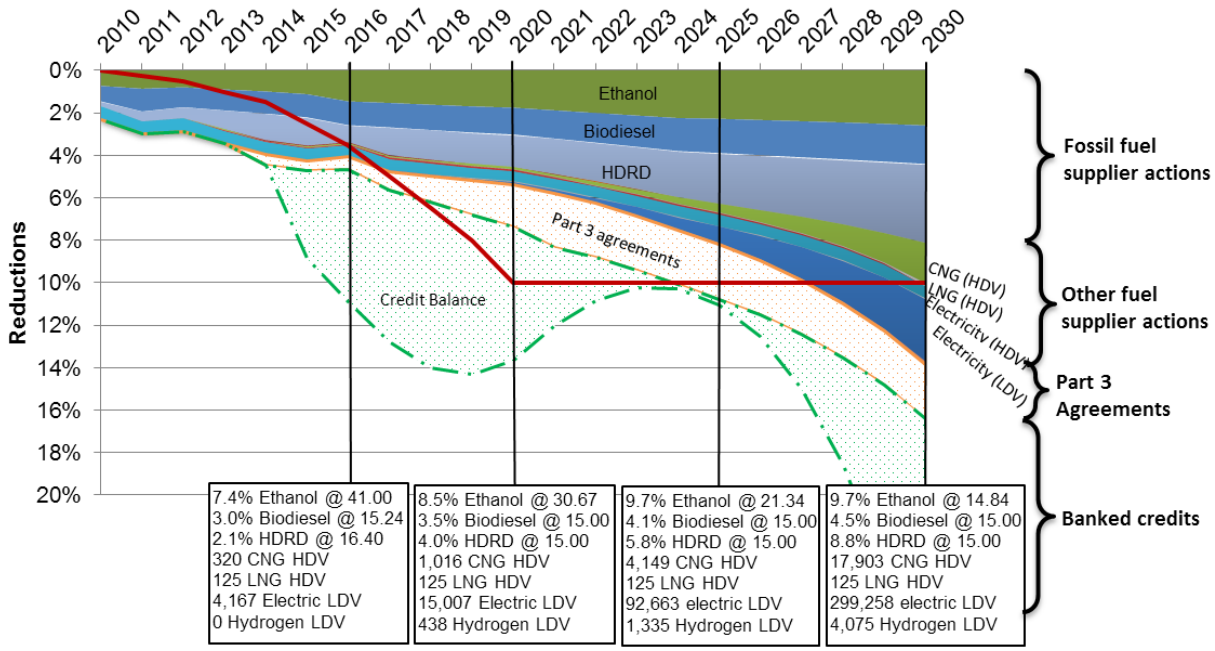

Figure 6. An example of a compliance scenario for fuel suppliers in B.C. (B.C. Ministry of Energy, Mines and Petroleum Resources, 2018). In addition to conventional and advanced biofuels, natural gas, renewable natural gas, electricity, hydrogen and propane are considered in this compliance scenario.

B.C. uses GHGenius, an ISO compliant LCA model, to calculate the carbon intensity of all fuels currently supplied to the province. Direct land use change is included in GHGenius, but indirect land use change has not yet been included as a factor because there is currently no international consensus on the methods and models needed to reliably calculate indirect greenhouse gas emissions, and there is no strong evidence that the low volumes of feedstocks used in domestic production of biofuels have resulted in indirect land use change. Grains used for domestic production have come from agriculture land that continues to produce higher yields. In the case of corn, the demand from biofuels in large part replaced the loss in demand for feed when many livestock operations closed in Eastern Canada.

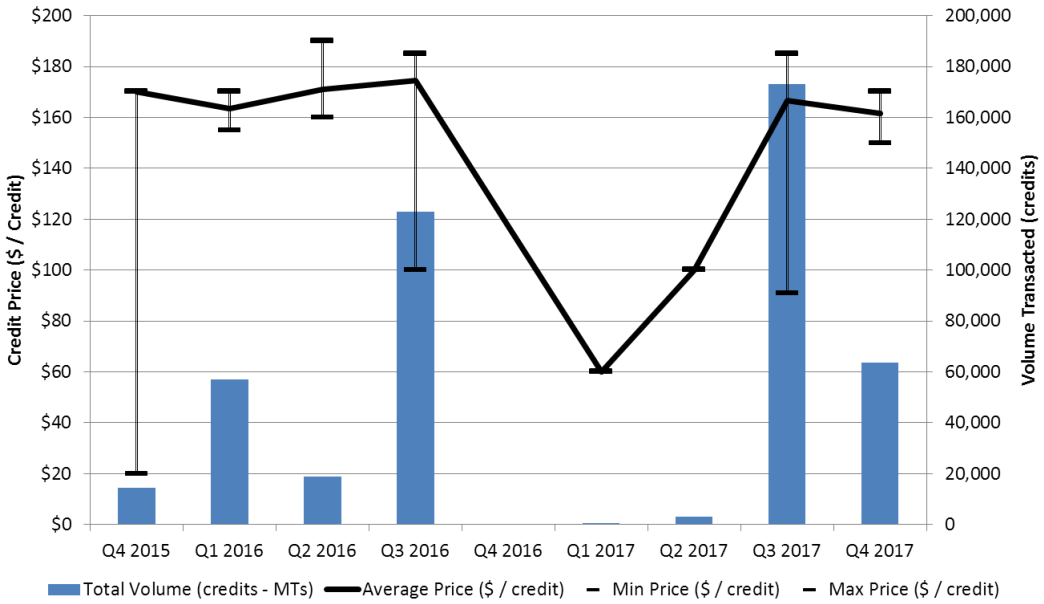

Figure 7. Quarterly LCFS credit price and transaction volume, 2015-2017 (B.C. Ministry of Energy, Mines and Petroleum Resources, 2018)

Fuel suppliers have shown a strong preference towards blending HDRD due to its better cold weather properties and fungibility with fossil diesel, however it is more expensive to produce than FAME biodiesel. As demand for the HDRD product has increased globally, the price of low carbon product credits has risen, and the price of BC-LCFS compliance credits has remained high as well, as shown in Figure 7.

One mechanism to keep the cost of compliance credits from rising to undesirable levels is “Part 3 Agreements" which is unique to the BC-LCFS. Under this mechanism, the director of the BC-LCFS may enter into an agreement with a fuel supplier to award compliance credit for activities that have a reasonable chance of increasing the supply of low carbon fuels in B.C. This has encouraged a number of activities, including the investigation of co-processing bio-crude with fossil crude oil at existing petroleum refineries. The resulting fuels meet all standards for conventional fossil fuel but contain renewable content, which can potentially reduce the carbon intensity of the fuels. The program has been fully subscribed to date. Details are available online in Information Bulletin RLCF-014. B.C. refiners are investigating a range of potential feedstocks, including ones that are not yet available at commercial scale, incenting a significant amount of research activity.

B.C. is planning to further develop its LCFS through several programs that are under consideration, including a possible 15% reduction target by 2030, new mechanisms to strengthen credit markets and manage price volatility, recognition of GHG emission reductions achieved through petroleum refinery improvements, and the investigation of new classes of fuels such as biojet and alternative low carbon marine fuels.

In the News

Reports and Research

July 24 – EIA released its International Energy Outlook 2018 (IEO2018). This report focuses on how different drivers of macroeconomic growth may affect international energy markets in three heavily populated and high economic growth regions of the world: China, India, and Africa. To perform this analysis, EIA updated the IEO2017 Reference case with new macroeconomic information and varied macroeconomic assumptions to create side cases for each region. See the full report at: http://www.eia.gov/outlooks/ieo/

Other notable IEA publications from the first half of 2018 include:

- Market Report Series – Oil 2018 (March 2018): Global oil demand continues to grow, driven by developing countries in Asia, even as oil consumption growth slows down in China thanks to new environmental policies designed to curb air pollution. Strong growth in petrochemicals demand globally is another key area of growth. https://webstore.iea.org/market-report-series-oil-2018

- Perspectives for the Energy Transition: The Role of Energy Efficiency (April 2018): In support of its presidency of the G20 in 2017, the German government requested IEA and the International Renewable Energy Agency (IRENA) to explore how an energy transition to address climate change might look. In this follow-up study, the IEA takes stock of progress towards a low-carbon energy sector and provides further insights into the fundamentally important role of energy efficiency to achieve a clean energy transition. https://webstore.iea.org/perspectives-for-the-energy-transition-investment-needs-for-a-low-carbon-energy-system

- Renewable Energy Policies in a Time of Transition (April 2018): Spurred by innovation, increased competition, and policy support in a growing number of countries, renewable energy technologies have achieved massive technological advances and sharp cost reductions. Renewables have come to the forefront of the global energy transition, with nearly every country adopting a renewable energy target… https://webstore.iea.org/renewable-energy-policies-in-a-time-of-transition

- Energy Technology RD&D budgets 2018: Overview (May 2018): This is a short overview of the Energy Technology RD&D budgets database. This database includes data on budgets in national currencies (in nominal and real prices), in USD (at latest year prices and exchange rates), in USD (at latest year prices) and in Euro (at latest year prices). Also, the database shows RD&D budgets and calculated financial indicators. https://webstore.iea.org/energy-technology-rdd-budgets-2018-overview

- World Energy Investment (WEI) 2018 (July 2018): This report provides a critical benchmark and reference for decision making by governments, the energy industry, and financial institutions to set policy frameworks, implement business strategies, finance new projects, and develop new technologies. It highlights the ways in which investment decisions taken today are determining how energy supply and demand will unfold tomorrow. https://www.iea.org/wei2018/

- Bioenergy in Canada (July 2018): This short article provides the current status of bioenergy production and use in Canada. Some of the outcomes of the recent ExCo81 meeting in Ottowa, Canada are also described in this report. http://www.ieabioenergy.com/wp-content/uploads/2018/07/IEA-Bioenergy-News-Volume-301-July-2018.pdf

Policy and Regulatory Developments

July 23 – This Los Angeles Times article discusses California's achievement of hitting its targets to reduce greenhouse gas emissions below 1990 levels four years early, with a closer look at the state's Air Resources Board data showing that while emissions from electricity generation in California have indeed plunged, other key industries have remained flat in terms of emissions reductions, with pollution from transportation still increasing (read more).

August 22 – The Canadain government is challenging Canadians to develop sustainable and affordable bio-jet fuel that reduces the aviation sector's carbon foot print. The federal government announced a nationwide challenge to develop the cleanest, most affordable and sustainable aviation fuel to further reduce the carbon footprint of the aviation sector. Further details about this program can be found here.

September 10 – The Federation of German Bioethanol Industry (BDBe) released an interactive map on European biofuels showing the Biofuel regulations and blending targets in 30 European countries. This map can be accessed here.

September 10 – In 2016, California's GHG emissions levels were below 1990 levels for the first time since emissions peaked in 2004. That's equivalent to taking about 12 million cars off the road or saving 6 billion gallons of gasoline a year. The figures, released in July 2018, show promise for the state's maturing emissions reduction goals (read more).

Industry News

May 3 – Air Canada announced its Edmonton-San Francisco flight of a 146-seat Airbus A320-200 aircraft on May 2 operated on biofuel. The larger aircraft was scheduled for the flight to accommodate a trade mission delegation to California led by the government of Alberta, the city of Edmonton and Edmonton-area businesses (read more).

May 12 – In Texas, Neste U.S., Inc. celebrated its 1 billionth gallon of Neste MY Renewable Diesel sold in North America, which has effectively helped reduce more than seven million metric tons of GHG emissions to the Earth's atmosphere. This is the equivalent of removing 1.6 million passenger vehicles from the road for one year (read more).

May 14 – KLM Royal Dutch Airlines now flies to Växjö, Sweden every day, and to make these flights as sustainable as possible, KLM is investing in 120,000 litres of sustainable aviation fuel per year for this new Swedish destination. KLM guarantees it will purchase 5% sustainable aviation fuel, based on all flights to and from Växjö. Together with key regional partners, such as Södra, Sweden's largest cooperative of forest owners, Växjö Småland Airport and the City of Växjö, KLM and SkyNRG will conduct a feasibility study for local production of sustainable aviation fuel (read more).

May 16 – Fulcrum BioEnergy, Inc. announced the start of construction for Phase 2 of its first waste-to-fuels project, the Sierra BioFuels Plant (Sierra) and held a groundbreaking event at the plant site in McCarran, Nevada. The Sierra facility will be the nation's first commercial-scale plant converting a municipal solid waste (MSW) feedstock, or household garbage, that would otherwise be landfilled, into a low-carbon, renewable transportation fuel product (read more).

July 10 – In California, Cherokee Freight Lines, a northern California trucking company, switched its entire fleet of more than 200 trucks to run on Neste MY Renewable Diesel™ (read more).

June 19 – Fuel Delivery Services, Inc. (FDS), a bulk transporter of refined petroleum products, recently switched their Stockton, California-based fleet of trucks to Neste MY Renewable Diesel. FDS provides transportation services seven days a week, 365 days a year to a variety of clients, from small jobbers to major oil companies (read more).

July 26 – Second-generation ethanol production is overcoming the technical difficulties that had slowed its development and is now seen as commercially competitive with oil prices near $70 per barrel. Brazil's Raízen, a joint venture between Royal Dutch Shell Plc and Cosan SA Indústria e Comércio, is producing some 40 million liters of

cellulosic ethanol per year at its plant in Piracicaba, Sao Paulo state, Brazil. They recently reported solving early operational problems, with production currently stable and the plant hitting planned production numbers (read more).

August 14 – Andeavor is proposing to switch over its refinery in Dickinson, North Dakota from petroleum refining to the production of renewable diesel. Planned be operational in 2020, the feedstock will be waste and crop-based oils, the capacity will be 12,000 barrels a day (183 million gallons per year) using Haldor Topsoe's hydrotreating technology which removes the oxygen from organic oils and converts them to hydrocarbons (read more).

August 22 – The City of Vancouver, British Columbia, Canada signed a contract with Suncor to transition all its city vehicles to 100 percent renewable diesel. The city claims this will reduce its vehicle emissions to 50 percent below 2007 levels by the end of 2019 (read more).

August 30 – India has flight-tested its first biofuel-powered plane that aims at cutting down air travel costs. The 72-seater Bombardier Q400 turboprop aircraft, powered by a mix of biofuel and air turbine fuel, took off from Jolly Grant airport in the northern state of Uttarakhand's capital Dehradun for the Indian capital (read more).

September 12 – Clariant, a world leader in specialty chemicals, started construction of its first large-scale commercial sunliquid® plant for the production of cellulosic ethanol made from agricultural residues (read more).

September 16 – Agrisoma, United Airlines and World Energy completed the longest transatlantic biojet flight yet. Lots of biofuel flights have been happening over the last few years, so why is this one different? First, at 11 hours long, it's the longest transatlantic biojet flight yet. Second, it's running on carinata, but what exactly is carinata? Why is it so captivating? What does this transatlantic biojet flight really mean for the future of this happy little plant, for Agrisoma, for the future of aviation? (read more)

Upcoming Meetings & Conferences

2018

October

- Argus Biofuels 2018 — October 8 – 11, 2018 — London, UK
- Biofuels International Conference and Expo — October 10-11, 2018 — Berlin, Germany
- 8th International Conference and Exhibition on Biopolymers and Bioplastics — October 15-16, 2018 — Las Vegas, Nevada, USA
- Algae Biomass Summit — October 14-17, 2018 — The Woodlands, TX
- 7th International Symposuim on Energy from Biomass and Waste —15-18 October 2018 — Venice, Italy
- Bioenergy Australia Conference, Driving Commercial Outcomes — October 16-18, 2018 — Brisbane, Australia
- 13th International Congress on Biofuels and Bioenergy — October 18-20, 2018 — Ottawa, Ontario, Canada
- European Forum for Industrial Biotechnology and the Bioeconomy (EFIB 2018) — October 16-18, 2018 — Toulouse, France
- Argus Biofuels & Carbon Markets Summit — October 22-24, 2018 — Napa Valley, CA
- TAPPI's International Bioenergy & Bioproducts Conference (IBBC) — October 28 – 31, 2018 — Portland, Oregon
- AIChE's 2018 Annual Meeting — October 28 – November 2, 2018 — Pittsburgh, PA

November

- Scaling Up 2018 — November 5 – 7, 2018 — Ottawa, Ontario, Canada
- ABLC Global 2018 – IEA Bioenergy Conference 2018, November 7-9, 2018, San Francisco, USA
- Aviation Carbon 2018 — November 5-6, 2018 — London, UK
- World Ethanol & Biofuels Conference — November 6-8, 2018 — Brussels, Belgium

- International Conference on Biofuels and Bioenergy, November 12- 13, 2018, Athens, Greece

December

- CAAFI Biennial General Meeting (CBGM) & ASCENT Symposium — December 4-6, 2018 — Washington, DC
- Roundtable on Sustainable Biomaterials Annual Meeting — December 6-7, 2018 — Berlin, Germany

2019

January

- Biomass Trade Summit Europe 2019 — 16-17 January, 2019 — Rotterdam The Nethelands
- Industrial Biotechnology for a Sustainable Future — January 30-31, 2019 — Glasgow, Scotland

February

- 13th International Conference on Biofuels and Bioenergy — February 18-19, 2019 — Amsterdam, Netherlands

IEA Bioenergy Task 39 Meetings

The following is an abbreviated schedule of Task 39 events and meetings planned over the next 9 months. Please contact us for more detailed information:

- The next IEA Bioenergy Task 39 meeting will be 5-6 November 2018 in San Francisco, held in conjunction with the IEA Bioenergy ExCo82 end of triennium meeting and Advanced Bioeconomy Leadership Conference GLOBAL ("ABLC GLOBAL") being held 7-9 November.