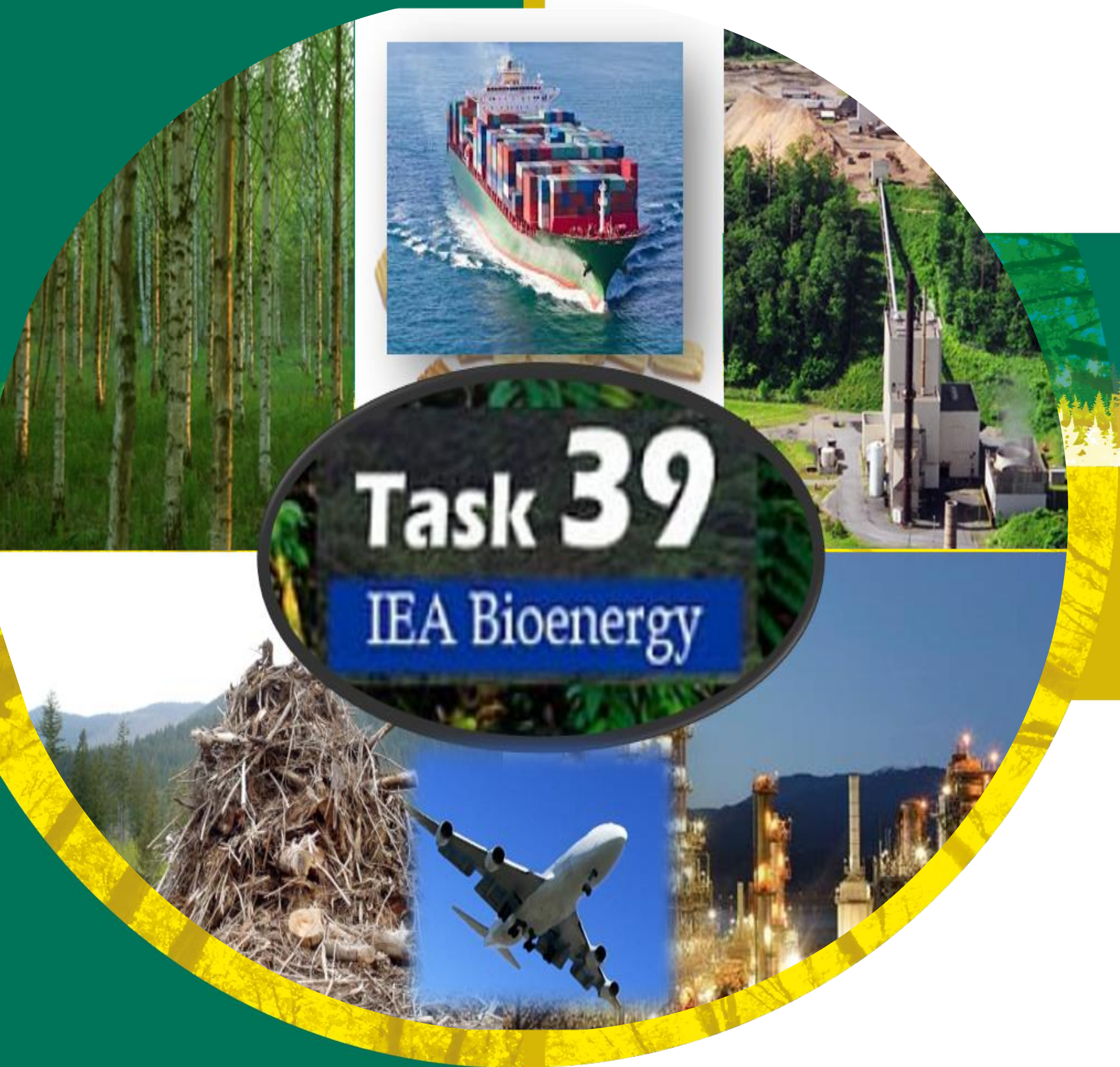
Executive Summary

'DROP-IN' BIOFUELS:

The key role that co-processing will play in its production



Front cover information panel

IEA Bioenergy

IEA Bioenergy: Task 39: January 2019

Executive Summary

'DROP-IN' BIOFUELS: The key role that co-processing will play in production

Susan van Dyk
University of British Columbia, Canada

Jianping Su
University of British Columbia, Canada

James D. McMillan
National Renewable Energy Laboratory, USA

Jack (John) N. Saddler
University of British Columbia, Canada

ISBN, 978-1-910154-62-5

Published by IEA Bioenergy

‘DROP-IN’ BIOFUELS –The key role that co-processing will play in its production

EXECUTIVE SUMMARY

In this report, “drop-in” biofuels are defined as “liquid bio-hydrocarbons that are functionally equivalent to petroleum fuels and fully compatible with existing infrastructure”. The predominant drop-in fuels produced today are made by converting ”conventional” oleochemical feedstocks such as vegetable oils, used cooking oils, tallow, and other lipids to fully saturated products. As about 5 billion litres of hydrotreated vegetable oils (HVO’s)/ hydrotreated esters and fatty acids (HEFA’s) are produced worldwide each year this technology is considered “conventional” because it is fully commercialized. However, sourcing large quantities of “sustainable” oleochemical (lipid) feedstocks at a low enough cost to result in profitable drop-in biofuel production remains challenging and is a major constraint limiting the expansion of this production platform. Consequently, it is likely that “advanced” thermochemical technologies such as gasification, pyrolysis or hydrothermal liquefaction (HTL) based on more widely available biomass feedstocks will provide much of the long-term supply of drop-in biofuels in the future. However, progress in technology development and commercialisation of these advanced technologies has been slow owing to a combination of low fossil fuel prices and on-going uncertainty about long term energy policies.

However, whether the feedstocks or fungible fuel intermediates for drop-in biofuels production are produced via the oleochemical or thermochemical routes, the closer integration of the upgrading stage for fuel production through a refinery co-processing strategy will likely have a significant impact on the rate and scale of future expansion of drop-in biofuels. As indicated in the original, 2014 report, biochemical routes to drop-in biofuels are unlikely to supply significant volumes as the intermediates (e/g. butanol, farnesene, etc.) produced via this route are worth more than fuel and will likely only be used extensively once the biochemical market is saturated. However, this route to biojet production was certified relatively early and although sometimes considered as more of a “niche” product, has been used in several demonstration and commercial flights.

While increased levels of electrification of transport will be essential to reduce global warming GHG emissions, “green electricity” is poorly suited for key transportation sectors. Sectors such as aviation will be reliant on low carbon drop-in biofuels to achieve significant emission reductions, while other long-distance transport sectors such as shipping, rail and long-distance trucking, are also predisposed to using drop-in biofuels.

This update of the 2014 IEA Bioenergy Task 39 “drop-in” biofuels report reviews the status of technologies, the progress of the various technical approaches and updates the successes, challenges and obstacles that have been encountered during the commercialization of drop-in biofuels. A major focus has been to assess the opportunity to use existing (idled or in use) petroleum refinery infrastructure to co-process feedstocks/intermediates such as lipids, oleochemicals, bio-oils and biocrudes to finished, drop-in biofuels.

The relatively high levels of oxygen present in potential biological feedstocks such as lipids and lignocellulosic materials/biomass, relative to petroleum crude oils, poses some challenges to the efficient production of drop-in biofuels. Feedstocks with higher oxygen levels (>40%), such as sugars and biomass, are more difficult to upgrade into drop-in biofuels as they require increased processing and greater amounts of hydrogen for hydrotreatment. Feedstocks with lower oxygen content, e.g. HTL biocrudes or catalytic pyrolysis oils are “easier” to upgrade and consume less hydrogen. As was mentioned earlier, the important role that renewable / low carbon (green) hydrogen will play in upgrading biological feedstocks will continue to be a key challenge for the future development of drop-in biofuels, particularly finding cost-effective, renewable sources of hydrogen. With worldwide fuel standards imposing ever stricter limits on sulphur, especially for marine fuels (as set by the International Maritime Organisation[1]), global hydrogen demand will increase and place an additional burden on existing refinery capacity. Although the potential competition for hydrogen between petroleum and drop-in biofuel refineries was highlighted earlier, as detailed in the current report, if a co-processing strategy with oil refinery integration is pursued, access to hydrogen should become a less significant obstacle to drop-in biofuel development. However, it is still anticipated that there will be increasing competition for hydrogen, both as a potential fuel in its own right, and also within current and future refinery operations. As well as co-processing strategies, the current report assessed different hydrogen production technologies. Steam reforming of natural gas will continue to be the most prevalent route to hydrogen production, as well as being the most cost-competitive under current policy and market conditions. However, for drop-in biofuels technologies where high hydrogen inputs are required to deoxygenate the feedstock, (such as upgrading of fast pyrolysis oils), the source of the hydrogen will have a significant impact on the life cycle assessment (LCA) of these biofuels.

PETROLEUM REFINERIES VERSUS DROP-IN BIOREFINERIES

Drop-in biofuel production generally proceeds in two distinct phases that includes the production of upgradable intermediates, e.g., fast pyrolysis and HTL-derived oils or virgin/waste lipids, and a second phase of upgrading the intermediates into a finished fuel blendstock(s). As was described earlier, crude oil is "refined" through various refinery processing steps including distillation, cracking, hydroprocessing, etc. Many of these processing steps will also be needed to upgrade "biocrude/bio-oil" intermediates into drop-in biofuels. While there are differences between crude oils and biogenic intermediate feedstocks, almost all types of drop-in biofuels require some form of hydroprocessing or hydrotreatment similar to processes found in petroleum refining. For some bio-intermediates, e.g. bio-oils, advanced processing such as catalytic cracking, isomerisation or fractionation is also required to allow the finished fuels to meet specifications. Currently, the dominant route to making drop-in biofuels has involved the upgrading of biobased feedstocks, primarily oleochemicals, in biorefineries. This has been termed the oleochemical/lipid ("conventional") pathway, with companies such as Neste, World Energy and others operating biorefineries that hydrotreat animal and vegetable fats/oils to produce biofuels. To date, this is the only pathway that has produced significant volumes of drop-in biofuels. However, to provide the much larger drop-in biofuel volumes that are needed it is likely that thermochemical technologies using biomass feedstocks will have to be fully commercialised. Progress has been slow, with the total volume of biocrudes/bio-oils commercially produced on a routine basis remaining limited. Some trials have occurred where biocrudes have been successfully upgraded to drop-in biofuels and this work has helped identify possible solutions to problems that have been encountered.

However, most of this work has focused on upgrading fast pyrolysis oils into drop-in fuels such as diesel or gasoline. For applications such as heating oils or co-firing with natural gas, as demonstrated by BTG, Ensyn, these "fuels" can be readily used without upgrading. The less developed second stage of upgrading fast pyrolysis oils involves the upgrading of the stabilized intermediates into finished fuels. It is this second stage that most closely resembles petroleum refining and which offers enormous potential for cost saving through refinery integration. While

[1] A sevenfold decrease in sulfur content in fuels required by 2020

refinery integration and/or co-processing of biobased intermediates in existing refineries are prominently featured in this report, this it is not the only route to upgrading biocrudes. As was covered extensively in the previous, 2014 report, freestanding upgrading in dedicated biorefineries, as demonstrated by companies such as Neste, is also a viable approach.

THE KEY ROLE OF REFINERY INTEGRATION AND CO-PROCESSING

Although the potential for integration between petroleum refineries and biorefineries based on a co-processing strategy was discussed previously, in this update co-processing is highlighted as being key to the expansion of drop-in biofuel production, specifically addressing the second, upgrading, stage. It is suggested that, utilisation of existing refinery infrastructure for co-processing of biobased intermediates will greatly facilitate the future development and expansion of low carbon drop-in biofuels by creating a commodity market for intermediates. It is also highly likely this will enhance the accelerated production of liquid bio-based intermediates that can then be upgraded into finished fuels in bulk at existing refineries. The disparity in oxygen content between crude oils (<2%) and bio-intermediates, such as fast pyrolysis oils (>40%) or HTL biocrudes (<20%), will have an impact on refinery operations.

Depending on the nature of the intermediate and its chemical characteristics (e.g. oxygen content), various refinery insertion points, such as hydrotreaters or fluid catalytic crackers (FCCs) could be more or less suitable. Further work will have to be carried out to determine the impact of various characteristics on refinery operations and products. The FCC is the most flexible processing unit as it is able to tolerate a variety of feedstocks, no additional hydrogen inputs are required, it "cracks" larger molecules into smaller ones and it is primarily used for gasoline production. As it is widely recognised that "cracking" of the larger molecular weight intermediates that tend to predominate in many biocrudes/bio-oils will be needed to produce drop-in biofuels, the FCC offers an "easier-and less-risky" insertion point in existing petroleum refineries. Another potential benefit is that the FCC catalysts are typically regenerated on site, which means that catalyst deactivation, i.e., reactivation/regeneration, can be more readily addressed.

In contrast, hydrotreaters generally use expensive catalysts that are sensitive to inhibition and deactivation and they are typically regenerated off-site every few years. They are not usually used to crack large molecules into smaller molecules but rather as processing units to produce finished fuels (fuel blendstock(s)) by removing contaminants such as sulphur, nitrogen and oxygen (typically found at relatively low concentrations in fossil feeds). Further work at the refinery level will have to be carried out to de-risk this process as an insertion point.

The choice of whether to use an FCC or hydrotreater for bio-intermediate upgrading will largely depend upon a refinery's configuration and the specific nature of the intermediate/biocrude/lipid feedstock. For example, the recent amendment to ASTM 1655 that allows the production of jet fuel through co-processing of lipids at up to 5% blends with petroleum crudes in existing refineries is predisposed to the use of hydrotreatment for upgrading and should enhance the production of a range of blended drop-in biofuels, not just biojet fuel. Initial co-processing supply chains are based on the "conventional" oleochemical route where hydrotreaters or FCCs are used to co-process/upgrade lipid/oleochemical feedstocks. Lipids have a relatively lower oxygen content (11%), when compared to lignocellulosic materials (~50%), and are chemically quite homogeneous (predominantly fatty acids), which simplifies their upgrading to drop-in biofuels. In contrast, the biocrudes produced by pyrolysis and HTL routes, although at different oxygen levels, both generate more variable and complex bio-intermediate feedstocks that are more difficult to upgrade into finished fuels, compared with fatty acids. The pyrolysis/HTL pathways are not currently certified by ASTM for the production of biojet fuels, using either freestanding upgrading or co-processing strategies. At this time, there does not appear to be any applications under review for biojet production via this route. It is therefore likely to take longer to develop the supply chains for these intermediates within a standalone or co-processing refining strategy. Consequently, this can be seen as a more mid-to-longer-term strategy. As hydroprocessing of biocrudes will likely take longer to become established, in the short-to-mid-term it is probable that these types on intermediates will be inserted into the FCCs, based on the lower risk associated with this approach.

Both conventional and advanced routes to drop-in biofuel production have been demonstrated, with the former already at a commercial scale. However, for both routes, ongoing research is still required to better understand how different biobased feedstocks behave in different reactor types at different blending levels (chemistry and reactions) and the consequential impacts on product characteristics. Equally important is the need to better determine the distribution of the renewable "bio-carbon" into the various product fractions, i.e., kerosene, gasoline, diesel, etc., produced during refinery operations. It is increasingly recognised that the renewable carbon content of the fuel will be a key metric when measuring the carbon reduction potential of finished fuels. This will likely form a central part of any policies designed to promote the production and use of drop-in biofuels. In parallel, techno-economic assessments of the different feedstock/reactor co-processing combinations will also be required to determine the economic viability of refinery integration.

It is likely that the various biobased intermediates, e.g. lipids, bio-oils and biocrudes, will originate or be produced from different feedstocks and various technologies, resulting in a range of chemical characteristics of these intermediates. Thus, to reduce the risk to the refinery, some form of "pretreatment/preliminary upgrading" of the biobased intermediates will be needed for stabilisation, removing contaminants, etc., prior to insertion into the refinery. If the "pretreatment/preliminary upgrading" step is situated at the refinery, a wider range of biobased intermediates could be accepted by the refinery and allow faster commercialisation of co-processing. It is also likely that some sort of supportive policies and other incentives will be required to encourage refineries to assess and implement these types of co-processing strategies.

PROGRESS IN DROP-IN BIOFUEL COMMERCIALISATION - OLEOCHEMICAL PATHWAY

Of the various drop-in biofuels that are currently being produced, renewable diesel is, by far, the largest volume product, with the vast majority of the renewable diesel derived from the hydrotreating of lipid/oleochemical feedstocks. It is also very likely that renewable diesel produced from oleochemical feedstocks will remain the most significant source of drop-in biofuels in the near term (one-to-five years). The production of "conventional" oleochemical-derived drop-in biofuels will help establish much of the supply chain that will be needed for "advanced" drop-in biofuels based on biomass feedstocks that are anticipated to be more plentiful and available at lower costs. The oleochemical route is also currently the major supplier of biojet fuels, with dedicated biojet fuel production taking place at World Energy (formerly Alt Air) in California. However, even at this facility, renewable diesel remains the major product. Current global, renewable diesel production is about 5 billion litres annually, dominated by freestanding facilities based on hydrotreating. More recently, there has been a trend towards re-purposing existing "under-performing" refineries or idled refinery infrastructure into renewable diesel refineries. Examples include ENI (Italy) and Total La Mede (France). Andeavour (USA) has also announced plans to convert a refinery in North Dakota[2].

As was highlighted earlier, the two main challenges of the oleochemical pathway are the cost/availability and the overall sustainability of the feedstock. As an example, some oleochemical feedstocks such as vegetable oils often cost more per tonne than the finished fuels they are used to produce. The competition between food/feed and fuel is also an ongoing concern that is driving policy in jurisdictions such as Norway and the EU. However, in other jurisdictions policies to support decarbonization for climate mitigation are playing a big role in promoting the ongoing production of oleochemical-based drop-in biofuels, to some extent overcoming the price differential. Jurisdictions such as California and British Columbia are currently a major destination for renewable diesel based on their low carbon fuel standards. The producer incentive for biobased diesels in the USA have also boosted the production of diesel biofuels for road transport rather than biofuels for aviation or shipping.

To try to resolve the feedstock cost and sustainability challenges associated with the oleochemical/conventional drop-in biofuel route, various companies have adopted two approaches. The predominant strategy has been to use lower cost and more sustainable "waste" oleochemical feedstocks such as used cooking oil, tallow and brown grease. However, these feedstocks are available in limited supply, leading to increased trade in used cooking oil, tallow and fish fats and oils with countries such as China, New Zealand and Australia exporting their supplies to "upgrading" facilities in Rotterdam and Singapore. The second approach that has been pursued is the development of alternative, "lipid" feedstocks such as jatropha, camelina, carinata, etc., based on the supposition that these crops can be profitably grown on marginal lands, thus minimising land use concerns. Although these approaches are ongoing, the development of new feedstock supply chains (from farmer to processing) have proven challenging and, at this time, only limited volumes of alternative feedstocks are available.

PROGRESS IN DROP-IN BIOFUEL COMMERCIALISATION FROM LIGNOCELLULOSIC FEEDSTOCKS - THERMOCHEMICAL PATHWAYS

Thermochemical technologies, based on more widely available and theoretically lower cost feedstocks such as biomass residues from agricultural and forestry residues will likely provide the longer-term feedstock supply for drop-in biofuels. However, commercialisation of these technologies has proven challenging, with progress slower than earlier forecast and the lack of long-term policy support also hampering development. As summarised below, there are two predominant thermochemical routes to producing drop-in biofuels, with gasification producing a gas intermediate and direct thermochemical liquefaction producing a liquid intermediate.

For many decades, commercial quantities of drop-in fuels have been produced using gasification combined with Fischer-Tropsch synthesis, with coal and natural gas used as the feedstocks. In 2009 this pathway to making alternative jet fuel was the first to receive ASTM D7566 certification, based on coal as the feedstock, with the South African company Sasol championing this application. However, when various groups have tried to develop variations of this technology using biomass or the cellulosic fraction of municipal solid waste (MSW) as the feedstock, significant challenges have been encountered. These included high initial investment costs, syngas clean-up after biomass gasification proving possible but expensive, biomass not proving to be such a low cost feedstock as anticipated and the scale of facilities based on coal and natural gas proving

[2] http://www.andeavor.com/refining/dickinson/dickinson-refinery-renewable-diesel-upgrade-project/

difficult to reproduce using biomass feedstocks.

To try to resolve some of these challenges, more recent gasification research has focussed on improved approaches, such as using plasma gasifiers to try to produce much cleaner syngas, thereby helping to overcome the significant challenges of syngas clean-up. However, plasma gasifiers are expensive to build and operate with projects such as Solena's proposed facility in the United Kingdom proving problematic. Other groups such as Fulcrum Bioenergy, who initially looked at plasma gasification, switched to a bubbling fluidized bed gasification technology, even though these gasifiers generally produce higher levels of tar. Fulcrum has tried to resolve this issue by combining this technology with steam reforming technology to produce cleaner syngas. Currently the Fulcrum Bioenergy facility is under construction in Nevada (USA), with completion expected by 2020[3]. Although the company is targeting aviation or biojet fuels, this will only be for a portion of the FT derived hydrocarbon mixture of liquids and fractionation and upgrading steps will still be required to make any drop-in biofuels. Other companies pursuing the Fischer-Tropsch route to drop-in biofuels include BioTFuel, developed by Total, and Velocys, which is developing small-scale Fischer-Tropsch technology at their ENVIA Energy plant based on gas-to-liquids conversion[4]. Red Rock Biofuels is following a related approach, using gasification of woody feedstocks combined with FT synthesis (licensed from Velocys) for their demonstration plant[5].

The other major thermochemical route to drop-in biofuels involves the production of a liquid intermediate via direct thermochemical liquefaction, followed by subsequent upgrading. While fast pyrolysis has been commercialised by companies such as Ensyn and BTG to produce fuel oil for heating applications, the upgrading step of converting fast pyrolysis-derived bio-oils to finished fuel blendstock(s) has not yet been commercialised.

Catalytic pyrolysis can be used to produce liquid bio-intermediates with a lower oxygen content and greater stability than uncatalyzed fast pyrolysis, bio-intermediates that are considered easier to upgrade into finished fuels. However, further research is required in this area, especially with respect to techno-economics and LCA.

Hydrothermal liquefaction (HTL) based processes are at an earlier stage of development, with companies such as Licella and Steeper Energy now pursuing construction of projects in Canada (Licella), the UK (Licella) and Norway (Steeper). Further is also needed on proving out economically appealing and scalable options of upgrading these HTL biocrudes.

Although a more stable bio-oil or biocrude with lower oxygen is highly desirable and easier to upgrade, the same type of upgrading refinery infrastructure as fossil crudes will be required to upgrade the fast pyrolysis- or HTL-derived liquid intermediates into higher specification fuels. An ongoing consideration is the trade-offs between the production of lower-oxygen content intermediates (such as HTL-derived biocrudes) which will require less upgrading, as compared to a higher-oxygen content intermediate (such as a fast pyrolysis-derived biocrudes) which will require more upgrading. It should be noted that in all cases upgrading of liquid intermediates derived from any of the thermochemical liquefaction technologies via refinery integration and co-processing is, potentially, a viable solution. However, technical progress remains at an early stage and significantly more research is still needed to better understand the co-processing behaviour of

[3] https://www.prnewswire.com/news-releases/fulcrum-bioenergy-breaks-ground-on-sierra-biofuels-plant-300649908.html

[4] https://www.velocys.com/envia-oct-2017/

[5] https://www.biofuelsdigest.com/bdigest/2018/07/29/red-rock-biofuels-facility-breaks-ground-in-lakeview/

the various biobased intermediates and their economic potential.

PROGRESS IN DROP-IN BIOFUEL COMMERCIALISATION FROM LIGNOCELLULOSIC FEESTOCKS - BIOCHEMICAL AND HYBRID PATHWAYS

It was previously suggested that the various biochemical routes to drop-in biofuels were unlikely to be economically attractive primarily because, in many cases, the biochemical intermediates are worth more than the finished fuels. For example, most biochemical pathways can produce highly functionalised molecules that are more suitable for higher-value applications in the broader biochemical sector. Nonetheless, companies such as Gevo and Lanzatech continue to actively pursue drop-in biofuel production from biochemical intermediates (butanol and ethanol, respectively), primarily focusing on upgrading to premium biofuels suitable for aviation. These routes to biojet fuels have received ASTM certification, giving these fuels ready market access and a significant demand for the limited supply. As a result, a good number of flights using blends of aviation biofuels derived from either Amyris' direct sugar to hydrocarbon pathway (DSHC) or Gevo or Lanzatech's alcohol-to-jet (ATJ) pathways (isobutanol to biojet and ethanol to biojet fuel, respectively) have occurred and have received considerable publicity. However, while technically proven, it is likely that the cost competitiveness of biojet fuels derived via these routes will continue to be challenging.

Over the last few years there has been increased interest in the Power-to-Liquid (PtL) routes to drop-in fuels production, particularly in Europe. This technology is based on carbon capture technologies combined with renewable hydrogen generation through electrolysis of water and the synthesis of longer chain hydrocarbons through technologies such as Fischer-Tropsch and methanol-to-hydrocarbon routes. If successful, this pathway offers significant advantages as these drop-in fuels can be used within existing infrastructure while avoiding the sustainability challenges that are sometimes associated with using non-waste biomass. The Power-to-Liquid (PtL) fuels route can also serve as a form of "energy storage" by using excess renewable electricity to create readily storable liquid hydrocarbon fuels. However, it is anticipated that the considerable economic and competition (for green electricity) challenges will limit the development of the Power-to-Liquid (PtL) fuels route in the near term.

THE ROLE OF POLICY IN THE DEVELOPMENT OF DROP-IN BIOFUELS

Long term, supportive policies that provide financial and market stability to both producers and users of drop-in biofuels will be key to catalysing the full commercialisation of drop-in biofuels. No significant developments have occurred in the absence of such policies. However, the predominant type of policies used to date are volumetric mandates with the EU introducing significant (3.5% by 2030) specific targets for advanced biofuels as part of its RED II legislation. This alone will not be adequate if climate change mitigation is a primary goal. A lower carbon intensity (CI) for drop-in biofuels will also have to be ensured. As a prime example, the low carbon fuel standards that have been legislated in jurisdictions such as California and British Columbia have played a key role in promoting increased drop-in biofuel production and use, with Germany and Sweden also introducing GHG reduction-based targets. These types of policies, which reward biofuels based on their emission reduction potential, must become more widespread if drop-in biofuel production and use is to become more widespread. In addition, sectors such as aviation, which are uniquely reliant on the development of lower carbon intensity drop-in biofuels, will likely require specific policies to support the production and consumption of so-called sustainable aviation fuel (SAF)/biojet fuel. Furthermore, the introduction of the new sulphur cap of 0.5% for marine fuel oils in Jan 2020 provides a significant market opportunity for biofuels.

It is likely there will be increased levels of electrification for transport in urban areas, with related factors such as air pollution, congestion, shared-economy, etc., all contributing to the development of electric light duty cars and trucks and short-route buses. However, sectors such as aviation and heavy-duty marine, rail and long-distance trucking are predisposed to needing low carbon intensity drop-in biofuels. As mentioned earlier, the current oleochemical and the future biocrude routes to drop-in biofuels result in the production of multiple products including renewable diesel, biogasoline and biojet fuel fractions. As drop-in biofuels are fully compatible with the existing fossil fuel-based transportation infrastructure they can be used in high blends or even neat (depending on fuel standards) resulting in significant emission reductions.

It is likely that the initial drop-in biofuels supply chain will be developed using lipid feedstocks and the oleochemical/conventional route to producing drop-in biofuels. The challenge of this pathway is not the technology, but rather the cost, sustainability and availability of the lipid/oleochemical feedstocks. In the mid-to-longer term, thermochemical pathways that make use of lower-cost, greater volume lignocellulosic-based feedstocks will be used to supply the significant volumes of drop-in biofuels that will be needed by the long-distance transport sectors. As high-level blends or "neat" drop-in biofuels are fully compatible with the current petrochemical infrastructure there is considerable potential to achieve significant emission reductions. Currently, transportation accounts for 23% of the global energy related carbon emissions and this is expected to increase as the economies of countries such as India and China continue to expand. As biofuels, primarily ethanol and biodiesel, only represent about 4% of the world's current transportation fuel supply, there is significant room for expansion of drop-in biofuel production and use. If successful, the increased use of drop-in biofuels can be expected to contribute significantly to decarbonizing transport and helping the world meet its climate mitigation targets.

CONCLUSIONS AND RECOMMENDATIONS

The vast majority of drop-in biofuel that is currently produced in the world is renewable diesel based on the oleochemical pathway, involving the upgrading of lipids via hydrotreatment. In the short-to-medium-term, this pathway will continue to supply the majority of drop-in biofuels, particularly for the renewable diesel and biojet fuel (Sustainable Aviation Fuel/SAF) markets. The production and use of these so-called "conventional" drop-in biofuels will establish the needed supply chains, with supportive policies helping bridge the price gap compared to the production and use of current fossil fuel-based transportation fuels. It is likely that future policies will increasing incorporate sustainability criteria such as carbon intensity (CI) that will further incentivise the development of "advanced" drop-in biofuels derived primarily via thermochemically-based processes using lower cost and more sustainably derived biomass and waste feedstocks.

As well as policies that encourage the production and sustainability of the feedstocks/bio-intermediates (e.g., lipids/biocrudes), supportive policies that encourage the development of the "upgrading" step will also be needed if we are to produce the required volumes of drop-in biofuels. The upgrading step is the main focus of this update report, as refinery co-processing will likely be key to the future expansion of drop-in biofuels production. As detailed and suggested in the main body of the report, the reconfiguration of current refinery infrastructure to enable the co-processing of biobased intermediates will greatly facilitate the production of low carbon drop-in biofuels. By creating a commodity market for intermediates such as lipids and biocrudes/bio oils this will enhance demand and accelerate production of bio-based intermediate liquids which can be subsequently upgraded at existing refineries to drop-in biofuels.

Current policies and market demands will continue to drive the development of "stand-alone" biorefinery facilities that are exemplified by companies such as World Energy (formerly Alt Air) who produce drop-in biofuels. However, it is likely that the need for lower carbon intensity transportation fuels will encourage the co-processing of fossil crude oils with low carbon intensity intermediates (lipids/biocrudes). It is probable that this will eventually become the predominant route to decarbonizing drop-in transportation fuels, with the “green molecules” supplied by the bio-intermediates ending up in each of the refinery’s major product fractions (i.e., kerosene, gasoline, diesel, etc.).

ACKNOWLEDGMENTS

We thank our former colleague Sergios Karatzos (now with Steeper Energy) for his considerable contributions to the original report and for his insights that contributed to many of the concepts described in this update report. This report is one of the outputs from the IEA Bioenergy’s Task 39 (Liquid Biofuels).

IEA Bioenergy

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
www.ieabioenergy.com/contact-us/