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Woodcote Media Limited
Marshall House
124 Middleton Road, Morden,
Surrey SM4 6RW, UK
www.biofuels-news.com

MANAGING DIRECTOR
Peter Patterson
Tel: +44 (0)208 648 7082
peter@woodcotemedia.com

MANAGING EDITOR
Katie Woodward
Tel: +44 (0)208 687 4126
katie@woodcotemedia.com

EDITOR
Dawn Stephens-Borg
Tel: +44 (0)208 687 4183
dawn@woodcotemedia.com

INTERNATIONAL SALES MANAGER
Claire Smith
Tel: +44 (0)203 551 5751
claire@woodcotemedia.com

US SALES MANAGER
Matt Weidner
Tel: +1 610 486 6525
mtw@weidcom.com

PRODUCTION
Alison Balmer
Tel: +44 (0)1673 876143
alisonbalmer@btconnect.com

SUBSCRIPTION RATES
£170/€235/$270 for
6 issues per year
Contact: Lisa Lee
Tel: +44 (0)208 687 4160
Fax: +44 (0)208 687 4130
marketing@woodcotemedia.com

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Making the case for biofuels

On 22-23 October, over 200 representatives from the biofuels and bioenergy industry gathered at the Hotel Le Plaza in Brussels, Belgium to discuss the latest trends at the Biofuels International Conference & Expo. The annual conference, which was co-located with Bioenergy Insight's Biogas Congress & Expo and Biomass Congress & Expo, brought together leading producers, suppliers, regulators and other key industry players over a two-day period to discuss and debate the most pressing issues in the biofuels industry.

Day one of the conference kicked off with an update on the Renewable Energy Directive from Giulio Volpi, directorate general for energy at the European Commission. The European directive, which was revised in December 2018, establishes a binding renewable energy target for 2030 of at least 32%, with the aim of helping the European Union (EU) to meet its emissions reduction commitments under the Paris Agreement. Biofuels are undoubtedly instrumental in helping EU countries to meet their renewables targets in transport, with the directive setting out sustainability criteria for all biofuels produced or consumed in the EU. Volpi's overview of the achievements by EU Member States to date, as well as targets for 2030, was insightful, and set the scene for one of the conference's themes on the critical role of biofuels in reducing transport-related greenhouse gas emissions.

Continuing with this theme, presentations from Concawe's Marta Yugo and UPM's Marko Janhunun explored the role of low-carbon fuels in decarbonising the European transport sector. Yugo highlighted the limitations of batteries in powering larger and heavier vehicles, such as airplanes and containerships, making the case for low-carbon biofuels to fuel these transport modes in the future. Her key takeaways, however, were warnings to the industry: "The availability of large amounts of both renewable electricity and low-carbon feedstocks, including biomass, will be required," while "technology development and scale-up must be accelerated" to reach the European commitment to be a leader in global climate action.

After a successful first day, conference chair Ausilio Bauen, director of E4 Tech, welcomed back attendees into the grand

theatre of the Hotel Le Plaza – which, interestingly, was a former cinema built in the 1930s – to kick off proceedings on day two. Delving into more detail, the day's presentations focused on two key emerging areas for biofuels: aviation and marine applications. Karlijn Arts, policy and sustainability manager at SkyNRG, offered a brief but insightful history into the sustainable aviation fuel (SAF) market and developments achieved to date. Leading the way for SAF, SkyNRG is developing the first dedicated production plant for the sustainable fuel in Europe: the DSL-01 plant in Delfzijl, the Netherlands. The facility, which is on schedule for commissioning in 2022 and recently received support from Shell Aviation, will produce 100,000 tonnes of SAF annually, corresponding to a reduction in lifecycle carbon dioxide (CO_2) equivalent emissions of around 270,000 tonnes. This commitment to advance the case of sustainable aviation fuel was applauded by conference attendees, and is an excellent example of the commitment needed to decarbonise the aviation sector.

Stratas Advisors' Cornelius Claeys (who has also contributed an article to this issue of *Biofuels International* (which you can read on page 16) highlighted CORSIA's impact on the global aviation biofuel market. The Carbon Offsetting and Reduction Scheme for International Aviation will cap net CO_2 emissions from international aviation at 2020 levels to achieve carbon-neutral growth. The resolution, according to Claeys, urges airlines to implement currently available fuel efficiency measures and to participate in a long-term switchover to using sustainable aviation fuels. In terms of adoption, "Scandinavian countries are taking the lead through blending mandates", Claeys said, with both Norway and Sweden committing to 30% biofuel blends in aviation fuel by 2030.

For a sector that is relatively new to the world of biofuels, the marine industry was thrown into the spotlight by GoodFuels' Rianne de Vries, who opened her presentation with a rather startling statistic: "Global shipping has annual carbon dioxide emissions comparable to the entire country of Germany; without action, shipping will account for 17% of global CO_2 emissions in 2050." Shipping currently uses the dirtiest fuel in the world, de Vries warned the audience, and legislation is only partially addressing this problem with the upcoming sulphur cap, due to come into force from 1 January 2020. The adoption of biofuels, however, is one of the best solutions available for marine applications, many of which can currently be used as a drop-in alternative solution to fossil fuel-based marine fuels. GoodFuels is well-placed to offer advice to shipowners and operators on the benefits of biofuels; the company, in partnership with biomass technology group BTG, recently announced plans for a major investment in a biorefinery to support shipping's low-carbon fuel demands. This development is definitely one to watch.

Each and every presentation over the two-day Biofuels International Conference & Expo drove home the same key message: biofuels have an essential role to play in the world's efforts to address climate change, and the industry must strive to innovate, develop and adopt technologies and clean fuels to reach this ambition.

If you're interested in speaking at next year's biofuels conference or sponsoring the event, please get in touch today to register your interest: marketing@woodcotemedia.com. And, of course, read on for even more analysis, case studies and trends as we look back on a year of progress in the biofuels industry, in the final issue of *Biofuels International* for 2019.

Katie Woodward
Managing Editor

New coalition led by Maersk to explore use of lignin, ethanol blend as marine fuel

A.P. Moller – Maersk has joined forces with Wallenius Wilhelmsen, BMW Group, H&M Group, Levi Strauss and Marks & Spencer to explore LEO, a blend of lignin and ethanol, as a potential future sustainable shipping fuel.

The LEO Coalition, which also includes Copenhagen University, will consider the environmental and commercial viability of LEO fuel for shipping. The sector currently accounts for 2-3% of global carbon dioxide emissions, and as such, has an urgent need to reduce its environmental impact.

"Shipping requires bespoke low-carbon fuel solutions which can make the leap from the laboratory to the global shipping fleet," explained Søren Toft, COO at Maersk. "Initiatives such as the LEO Coalition are an important catalyst in this process."

"Our customers' ambitions on sustainability are increasing rapidly, and we applaud this development," added Craig Jasienski, CEO of Wallenius Wilhelmsen. "Clearly, LEO would be a great step forward for supply chain sustainability, and it has the potential to be a viable solution for today's fleet, and not just a future vision."

Lignin is a structural bio-polymer that contributes to the rigidity of plants. It is isolated in large quantities as a by-product of lignocellulosic ethanol and pulp and paper mills, and is currently incinerated to produce steam and electricity.

Helena Helmersson, COO at H&M Group, added that "climate change is an ongoing reality and a key challenge to all industries, including fashion. We are aware of our responsibility to stay within the planetary boundaries and are committed to reduce our impact in every aspect of our value chain, including how our products are shipped to consumers around the world. This coalition gives us the opportunity to explore the development of a low-carbon fuel for shipping today."

Copenhagen University is currently undertaking a laboratory-scale development of LEO as a potential marine fuel. The project aims to move into a second phase – testing the fuel on vessel engines – in the second quarter of 2020.

A third phase, which will see the scaling up of LEO fuel production, will follow a successful second phase of the project. ●

Vertimass awarded up to $1.4 billion to optimise renewable jet fuel

Biofuels producer Vertimass has been chosen by the US Department of Energy's Bioenergy Technology Office to receive up to $1.4 billion (€1.25 billion) to optimise its renewable jet fuel.

The funding will help Vertimass commercialise its 'green' catalyst technology that converts ethanol into renewable jet fuel, which is compatible with current jet fuel infrastructure.

The technology is expected to enable the expansion of the liquid biofuels market beyond current constraints. Existing ethanol plants in the US have a current capacity of 16 billion gallons per year, a level that saturates current use as 10% blends with gasoline.

Veritmass' new catalyst breaks this barrier by producing a hydrocarbon that can be blended at much higher levels.

The technology also has the potential to overcome the problem of ethanol traditionally being considered too low in energy density for use as jet fuel. The new fuel could additionally be used to power heavy-duty diesel-powered vehicles, for which ethanol is currently not suitable.

The product aims to expand opportunities to use more corn-based ethanol in the US, cane sugar in Brazil, and cellulosic biomass elsewhere in the world. Initial tests show that the company's fuels, known as Vertifuels, are compatible for blending with gasoline, diesel and jet fuels without the need for engine modifications, with further testing underway for ASTM certification.

"We are excited to advance this unique technology for producing renewable jet fuel," said Dr. John Hannon, COO of Vertimass. "This technology will provide corn, sugarcane, and future cellulosic ethanol producers the opportunity to produce high value jet fuel that complements the ability of our technology to produce gasoline, diesel, and building block chemicals.

"Developing technology to reduce particulate emissions while increasing fuel energy density and optimising other key fit-for-purpose attributes can be invaluable in reducing greenhouse gas emissions to mitigate global climate change."

The technology is also able to convert a range of other alcohol feedstocks, including methanol, propanol and butanol, into gasoline, diesel and jet fuel blendstocks, as well as produce benzene, toluene, ethylbenzene and xylene (BTEX), which are used in the production of chemicals.

"The incorporation of this simple, low-cost technology into existing ethanol plants can rapidly transform these facilities into biorefineries with valuable flexibility to shift production among jet fuel, diesel and gasoline blendstocks, in addition to chemical building blocks, in response to market changes," added Charles Wyman, president and CEO of Vertimass.

"This new product can help meet the goals of the Renewable Fuel Standard, help California meet its low carbon fuel standard, and aid the Federal Aviation Administration in achieving their renewable aviation fuel targets. In addition, the ability to eliminate complete water removal from ethanol can result in energy content costs similar to those for fuel grade ethanol." ●

Demand for ethanol could fuel expansion of Brazilian farming land

A study carried out by researchers at the University of Queensland, Australia has shown that future demand for ethanol could potentially expand farming land used for sugarcane production in Brazil by five million hectares by 2030.

According to Milton Aurelio Uba de Andrade Junior, a researcher at the university's school of earth and environmental sciences, future biofuel demand will directly impact land use in Brazil, which produces ethanol from sugarcane.

"Our study has modelled scenarios forecasting future ethanol demand based on different trajectories for gross domestic product, population growth, fuel prices,

blending policies, fleet composition and efficiency gains," he said.

"A high demand scenario fuelled by strong economic and population growth, soaring gasoline prices, and ambitious blending targets, could mean that current demand for ethanol in Brazil will be doubled by 2030. If this scenario occurs, then Brazil will need an additional five million hectares of land for sugarcane crops to meet this high demand."

The majority of the additional sugarcane farms were likely to expand into pasturelands, minimising impact on native forests.

"A key assumption of our modelling is that Brazil's land-use policies, such as the sugarcane agro-ecological zoning, will continue to promote the increase of agricultural yields while minimising environmental impacts," de Andrade Junior added.

"However, in the current context of high uncertainty on the environmental agenda, such land-use policies need to be closely monitored and supported to ensure that the country's natural ecosystems and biodiversity remain protected."

The study was a collaboration between the University of Queensland, the International Institute for Applied System Analysis in Austria, as well as the National Institute for Spatial Research in Brazil. ●

HollyFrontier to build renewable diesel production unit at refinery in New Mexico

Texas, US-based petroleum refiner HollyFrontier has announced plans to construct a renewable diesel unit (RDU) at its refinery in Artesia, New Mexico.

Plans for the biodiesel plant, which was proposed to lower costs related to blending to renewable fuels, were announced alongside HollyFrontier's $1 billion (€0.9 billion) share buyback programme.

"Today's announcements illustrate HollyFrontier's commitment to both grow our business and deliver superior cash returns to shareholders," commented chairman of the board, Franklin Myers. "We expect our new renewable diesel plant will generate attractive returns and help us meet our requirements under the Renewable Fuel Standard. At the same time, we are increasing cash returns to shareholders through an increase in our regular dividend with a path for future dividend growth and a new HollyFrontier share repurchase authorisation.

"All of these actions are consistent with our balanced approach to capital allocation: 1) reinvest in and maintain our existing assets, 2) maintain a healthy balance sheet with an investment grade credit profile, 3) pay a competitive and sustainable regular dividend through the cycle, 4) invest in growth capital projects or acquisitions with a superior return, and 5) return excess cash to shareholders through share repurchases."

The RDU at HollyFrontier's Artesia refinery will have an annual production capacity of approximately 125 million gallons, enabling the company to process soybean oil and other renewable feedstocks into renewable diesel.

The new facility will help to meet demand for low-carbon fuels, while covering the costs of the company's annual Renewable Identification Number purchase obligation under the current market conditions.

Alongside rail infrastructure and storage tanks, the RDU is expected to have a total capital cost of $350 million (€316.4 million), and is due to be completed in the first quarter of 2022. The unit will be funded with cash on hand and is expected to generate an internal rate of return of 20-30%, the company added.

The share repurchase programme was authorised by HollyFrontier's board of directors, replacing all existing share repurchase authorisations, of which there was around $281 million (€254 million) remaining. Over the past 15 months, HollyFrontier has returned over $719 million (€650 million) to shareholders and reduced the outstanding share count by 8%.

BTG and GoodFuels to invest in marine biodiesel production facility

Dutch technology group BTG and sustainable marine fuel producer GoodFuels have teamed up to invest in a new biorefinery to support the demand for low-carbon shipping fuels.

BTG plans to establish a new technology company, to be called BTG-neXt, which will convert crude pyrolysis oil into biodiesel fuel suitable for use in the shipping sector. Both companies will invest in the construction of a biorefinery, which is expected to be the first in the world for an advanced marine biofuel based on pyrolysis oil.

Under the partnership, BTG-neXt will initially focus on building a pilot refinery to convert pyrolysis oil into 100% sustainable marine biodiesel, to demonstrate that continuous production is feasible. Pyrolysis oil is made from biomass-based residues, such as sawdust and roadside grass cuttings, and is a sustainable alternative to fossil fuels.

The new demonstration facility has a planned production capacity of just 1,000 tonnes per year, with plans to scale up if successful. The companies hope this facility will support the industry in meeting the target set by the International Maritime Organization (IMO) of a 50% reduction in greenhouse gas emissions by 2050, equivalent to an 85% reduction per vessel.

"This initial capacity is sufficient to demonstrate that the technology works and will serve as a basis for further scaling up our operations," said Rene Venendaal, CEO of BTG. The pilot is expected to require a six-figure investment, according to Venendaal: "We are now working on a more precise estimate of that figure."

BTG and GoodFuels plan to use the pre-commercial facility as a reference for rolling out commercial refineries with a capacity of potentially hundreds of thousands of tonnes per year of marine biodiesel.

BTG's plans for the biorefinery have been welcomed by GoodFuels, which sees sufficient potential in the project to explore the possibility of a collective investment in the demonstration plant.

"Over the last five years, GoodFuels has laid out a clear pathway for the use of biofuels in the shipping sector," commented Dirk Kronemijer, CEO of GoodFuels. "Together with partners such as Boskalis Loodswezen, Port of Rotterdam, Norden, Jan de Nul and its portfolio of GoodShipping A-Brand clients we have shown that these fuels will play an essential role in making shipping more sustainable.

"Crucially, the next step is to scale up the processes without making any concessions in terms of the sustainability of the feedstocks used. BTG's initiative meets all the success criteria, and we are very proud to work together with BTG to introduce this highly significant innovative technology in the Netherlands."

GoodFuels also intends to market the fuel produced by the pilot plant to further strengthen the commercial business case for scaling up the facility. ●

Norwegian cruise line Hurtigruten trials biodiesel on cruise ship

Hurtigruten has become the first Norwegian cruise line to begin testing biodiesel on board its cruise ships. The fuel, which is being tested on the MS Polarlys, can reduce emissions by up to 95%.

Commenting on the development, CEO Daniel Skjeldam said: "Biodiesel can in the long run potentially give a CO_2-reduction of as much as 95% compared to traditional marine fuels. Hurtigruten is testing certified biodiesel that is free of palm oil. The industry needs to start making more sustainable choices and Hurtigruten wants to lead the way."

The cruise ship has been trialling the use of biodiesel over the past few weeks, with testing expected to continue in the weeks ahead. The company noted that it's an important step for its plans to become emission-free.

"We are just at the beginning when it comes to using biodiesel in the shipping industry," Skjeldam continued. "We want to move the boundaries and learn more about how this can be used in a bigger scale. This can potentially transform the industry."

Hurtigruten banned the use of heavy fuel oil in its vessels 10 years ago, and is advocating for a global ban.

"Hurtigruten wants an international ban of use of cheap, polluting heavy fuel oil [in] the whole Arctic area and along the Norwegian Coast," explained Skjeldam. "It makes no sense to create more pollution and increase the risk of spills and destruction in areas that need to be protected." ●

US West Coast biodiesel producer SeQuential increases production by 30%

Crimson Renewable Energy subsidiary SeQuential, a commercial biodiesel producer on the US West Coast, has completed an expansion of its Salem, Oregon facility that has increased production capabilities by 30%.

The upgrade of the facility has increased production to 12 million gallons of low-carbon biodiesel per year. SeQuential has now increased production at the Salem facility every year since it began operations in 2008.

The recent expansion resulted in a new monthly production record of just over one million gallons of biodiesel in August, with ongoing production expected to continue at this rate. Upgrades made during the expansion also included additional storage and improved fuel blending and loading systems.

"We're thrilled to continue growing our production capabilities here in Oregon," said Tyson Keever, COO of SeQuential. "Local demand for low-carbon fuel has risen steadily over the past several years, thanks in part to the state's commitment to carbon reduction. We expect that trend to continue, and we wanted to be sure we're prepared to meet it."

The company has also recently expanded its cooking oil collection and recycling service territory to include the Los Angeles and Orange County areas of southern California. It now collects cooking oil from almost 20,000 customers across Oregon, Washington and California.

Cooking oil collected in the Pacific Northwest is used to make biodiesel at SeQuential's Salem facility, while oil collected in California is used in Crimson Renewable Energy's biodiesel plant in Bakersfield, California.

"SeQuential is committed to producing the lowest carbon fuel we can," said Harry Simpson, CEO of Crimson Renewable Energy. "A key part of that strategy is making sure we have good access to high-quality, low-carbon raw material. Expanding our service territory into southern California is a natural progression of SeQuential's used collection service and fits very well logistically with our Bakersfield biodiesel production facility."

SeQuential's biodiesel earned a carbon intensity rating of 14.85 under Oregon's Clean Fuels programme, making it the lowest carbon liquid fuel in the state.

Gevo, Blocksize Capital to track sustainability of renewable fuels using blockchain

Renewable fuels producer Gevo has teamed up with Germany-based blockchain company Blocksize Capital to track the sustainability of renewable products, including biofuels.

Blocksize provides distributed ledger technology DTL, more commonly known as blockchain, a tool that allows tracking of data with a product and the transactions associated with the product.

Gevo and Blocksize have discovered that it is possible to attach the key metrics for sustainability to gallons of fuel, enabling a 'sustainability' assurance that has not yet been used. The data associated with certain key metrics for measuring sustainability are able to be digitised through blockchain and could lead to tokenisation of those attributes.

"For years, we have been tracking the sustainability of the farms, and their farming practices, that supply products to our facilities, and we need to continue to do so as we expand," explained Patrick Gruber, CEO of Gevo. "We also track the amount and type of energy used in the production of our products. An end user who buys fuel should be able to simply access the data and know where those gallons originated and what the sustainability profile looks like.

"One of the key principles of sustainability is to 'measure, then improve'. DLT will enable us to sort out what truly is valuable in the end market, assigning the correct value to it, and then set up market mechanisms to share value upstream in the value chain. We want to create a system that rewards the value chain for improving its sustainability. Done right, we should be able to bring some of that value back to the farmer creating rewards for managing sustainability in agriculture.

"Obviously we'll target our ethanol, isobutanol, isooctane, and jet fuel first, but this type of tokenisation system could be applied to protein and feed, as well as chemicals, and food production too. It isn't lost on us that this type of blockchain technology has enormous potential beyond Gevo and its business system. A DLT-based system like the one we are developing with Blocksize is suitable for any type of business that needs to track sustainability attributes using agriculture or forestry to generate raw materials for the production of food, chemicals, feed, and fuels." ●

ExxonMobil to collaborate with Indian research universities on biofuels

ExxonMobil has recently signed agreements with the Indian Institute of Technology (IIT) locations in Madras and Bombay to expand its portfolio of research collaboration with India's universities, with research to focus on biofuels, gas conversion and emissions reduction in the industrial sector.

The five-year agreements between ExxonMobil and the Indian universities will specifically focus on research in biofuels and bio-products, gas transport and conversion, climate and environment, as well as low-emission technologies for the power and industrial sectors.

"These agreements will give us a better understanding of how to progress and apply technologies in India, and develop breakthrough lower-emissions solutions that can make a difference globally," said Vijay Swarup, vice-president of research and development at ExxonMobil Research and Engineering Company.

"IIT Madras is committed to providing sustainable solutions in the energy, chemicals and waste management sectors, and I am confident about our collaboration with ExxonMobil to achieve these goals," added Professor Ravindra Gettu, dean of industrial consultancy and sponsored research of IIT Madras.

"IIT Bombay values its relationship with ExxonMobil and the cause associated with it," noted Professor Milind Atrey, dean of research and development at IIT Bombay. "We are sure that this relationship will be long lasting and yield fruitful results."

These latest collaborations build on a series of partnerships established by ExxonMobil to progress innovative, lower-emissions research programmes with over 80 universities, five energy centres and numerous private sector partners around the world. ●

A summary of the recent explosions, fires and leaks in the biofuels industry

Date	Location	Company	Incident information
15/11/2019	**Story County,** Iowa, US	Verbio North America	Central Iowa officials were investigating a work-related death in Story County, Iowa on 15 November. According to a news release from Nevada police chief Ricardo Martinez II, an accident took place at Verbio North America's biorefinery in Nevada, 59219 Lincoln Highway. "First responders including police, fire, and an ambulance arrived on scene," Martinez II added. "Preliminary investigation determined the incident was an industrial accident. The injured subject died at the scene." Greg Northrup, president and CEO of Verbio, said that an investigation was ongoing but declined to add further comments. "Verbio is saddened by this tragic accident and we will fully cooperate with authorities in their investigation of the accident," he said in a written statement. "Employee safety is foremost in Verbio operations and we will be working with our subcontractors to ensure safe practices are being followed."
21/10/2019	Sacramento, California, US	N/A	Richards Boulevard along Interstate 5 was closed after a tanker truck carrying ethanol rolled over. The incident happened at approximately 10am on 21 October. The truck rolled over, causing a puncture in the tanker, which was carrying 7,500 gallons of ethanol at the time. There was an active leak, with fuel flowing down the embankment. Hazmat workers responded to the scene, according to a Sacramento Fire Department spokesperson. No injuries were reported.
15/10/2019	Crockett, California, US	NuStar Energy	A fuel storage fire broke out at NuStar Energy's ethanol plant in Crockett, California, at around 2pm on 15 October. The fire was contained by 9pm on the same day, although two tanks of ethanol fuel were still burning. A total of 15 acres of land were affected. The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) and other agencies are investigating the cause of the fuel tank explosions. It is possible that the event might be related to a nearby earthquake recorded 15 hours before the incident. On 25 October, two ships delivering imported ethanol were unable to unload their fuel, as the NuStar terminal is the only one in the San Francisco area able to receive ethanol. The terminal has been shut down by the state of California while the investigation continues. According to Contra Costa County hazmat chief, NuStar did not notify them of the tank explosion and fire at the fuel storage facility; it was the media who alerted them. No injuries were reported and the investigation into the explosion is ongoing.

Donnell Rehagen

The National Biodiesel Board looks back on a challenging year for the US biodiesel industry

Vision for the future

by Donnell Rehagen, CEO of the National Biodiesel Board

As we near the end of 2019, the US biodiesel industry is heaving a sigh of relief. This was a brutal year, with challenge after challenge. Many of the biggest challenges were on policy fronts we believe we had already addressed, including tax, trade and the Renewable Fuel Standard (RFS). It was during these repeated challenges that I was grateful that our association, the National Biodiesel Board (NBB), had outlined a path to navigate through situations just like these – a vision of where we wanted to be and how to get there.

The theme for our conference next year is Vision 2020. The theme is meant to set the tone for the industry but also to demonstrate a clear vision of what needs to be accomplished going forward. As the national trade association, our hope is that our vision of the future is clearer, sharper, and full of growth.

This year has not been a "vision" of success for our industry. Throughout 2019, the RFS was under attack from the increased issuance of small refinery exemptions and the fact that the biodiesel tax credit continued to be lapsed for nearly two years. Finally, the consideration of a changed circumstances review regarding our trade wins in Argentina created even more uncertainty. All of this is an indicator that our job is not done, and we will continue striving for policymakers to more clearly see a better path forward for biodiesel. We must boldly attack information gaps and educate those serving on the Hill. America's Advanced Biofuel cannot be a second thought to other renewable fuels, and we will advocate until it is in its rightful place as a significant economic and environmental influencer.

However, aside from the challenges faced, we have seen several victories throughout 2019. Earlier this year, the Northeast's heating oil industry resolved to achieve net-zero carbon dioxide (CO_2) emissions by 2050. The industry's resolution calls for a 15% reduction in CO_2 emissions by 2023, a 40% reduction by 2030, and net-zero carbon emissions by 2050. This collaboration between the heating oil and biodiesel industries to provide homes and businesses with low-carbon and low-greenhouse gas fuel options is truly a win-win, and we look forward to a continuing partnership.

Our industry has also continued to build and strengthen other partnerships with production agriculturalists during the course of the year. In 2019, NBB increased its collaboration with farmer leaders to amplify messaging. It is critical to industry success going forward that we continue to grow and expand our footprint by working in lockstep with supporting industries, such as our state and national soybean associations.

One way we commemorate the successes and build on these relationships is through our annual National Biodiesel Conference and Expo, where the industry's key players come together for a week of engagement and discovery. In 2020, the conference will take place on 20-23 January in Tampa, Florida at the Tampa Convention Center.

In addition to offering the opportunity to network, learn and do business, we are also rolling out several thought-provoking, news breaking sessions to provide the latest information regarding original equipment manufacturers, Bioheat® – a blend of ultra-low sulphur heating oil with renewable biodiesel – government affairs, technical advancements, and much more. We will also be announcing our new industry vision statement and strategy moving into 2020, and how we believe this new focus will advance biodiesel in the marketplace. ●

"America's Advanced Biofuel cannot be a second thought to other renewable fuels, and we will advocate until it is in its rightful place as a significant economic and environmental influencer"

For more information:
Visit: www.biodieselconference.org


Craig Willis

Passing key lessons and expertise from the US to Mexico

Promoting the benefits of ethanol

by Craig Willis, senior vice-president of global markets at Growth Energy

Over the past three years, we have seen a steady increase in the use of ethanol in North America as Canada, the US and Mexico look to biofuels to reach their economic and climate goals. The most recent adopter of ethanol, Mexico, has huge untapped market potential at nearly 1.2 billion gallons of ethanol over the next 10 years, and stands to reap significant environmental and economic benefits from the fuel. However, challenges still remain in approving the use of a 10% ethanol blend countrywide.

Ethanol in Mexico: dispelling myths

The Mexican ethanol fuel market is still in its infancy, only allowing the blending of ethanol in 2016, but it has already shown great promise for growth. Within a year of allowing blending, the Energy Regulatory Commission of Mexico approved increased blending[1] of ethanol fuel up to 10% outside of the country's three largest cities: Mexico City, Monterrey and Guadalajara. This has provided a significant market opportunity for both US and Mexican ethanol producers, but the restriction of sales in Mexico's three key cities has kept the country from unlocking its full potential. Misinformation has contributed greatly to the restriction of sales in these cities, and detractors spread this false information to protect their market share.

One major detractor is the oil interests who export methyl tert-butyl ether (MTBE), which is produced from a by-product of oil production, to Mexico. Currently, the country employs MTBE as the primary octane additive in its fuel, but recent studies have exposed a number of risks associated with this additive. Due to groundwater contamination concerns and its potential impact on human health[2], MTBE has been fully or partially banned in 25 states in the US[3] and functionally phased out of the US fuel supply in favour of ethanol fuel. With the near elimination of MTBE use in the US, MTBE producers have turned to Mexico and other countries for a market for their goods and attempted to undermine ethanol use abroad in the process.

Among Mexico's three restricted cities, Mexico City faces air quality issues on par with some of the most polluted cities on Earth, due to its large vehicle population and unique geography. And as we've experienced in the US, when the market share for oil is threatened, misinformation campaigns against ethanol begin to ensure a monopoly in the marketplace. In Mexico, ethanol critics are pointing to air quality concerns, yet a new study swiftly rebukes that false information[4] by showing that blending ethanol into the fuel supply would improve air quality in Mexico City, with 5.1% cumulative emissions savings.

The move to increase the blending cap for ethanol fuel in the country demonstrates that Mexican Government officials recognise the benefits ethanol fuels offer. However, the ongoing restriction in Mexico City, Monterrey and Guadalajara signals that more work is needed, and Growth Energy has committed to working directly with Mexican Government officials and stakeholders to ensure they are making informed decisions.

Engaging with Mexican decision-makers

In the past year, our association has conducted numerous trade missions to Mexico and participated in retailer and stakeholder meetings in both countries to not only provide educational opportunities, but also offer concrete tools and experience to help the country transition to higher blends of ethanol fuel.

One key initiative has been Growth Energy's workshop series, hosted alongside the US Grains Council (USGC) and the Mexican Association of Service Station Equipment Providers, launched earlier this year to educate retailers on ethanol-blended fuel and provide them with the tools to bring the fuel to their retail locations. These workshops offer Mexican retailers direct access to American fuel retailers, producers and ethanol experts, and ensure they have the latest science and data on ethanol's many benefits.

Additionally, Growth Energy has utilised trade missions to forge strong trade connections with Mexican Government officials and ensure they have access to that same science and data. Growth Energy CEO Emily Skor recently joined the USGC on a trade mission to Mexico City led by US Department of Agriculture secretary Sonny Perdue and undersecretary for trade and foreign agricultural affairs Ted McKinney. While there, Skor and our ethanol market development allies met with government officials and key industry stakeholders to promote the benefits of E10 and work to open Mexico's market nationwide. And I can't stress enough how central these face-to-face connections are to forge strong trade bonds and create new advocates for ethanol fuel.

Taking these steps ensures that stakeholders in Mexico are given direct access to American producers and retailers and allows us to share with them the success that ethanol has had in the US. We will continue to lead our industry in engaging with Mexico's ethanol supporters to promote the economic and environmental benefits of ethanol fuel in the country. ●

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Emmanuel Desplechin

How renewable ethanol can help EU countries be more effective at reducing emissions

Focus on fuel quality

by Emmanuel Desplechin, secretary-general at ePURE

In the ever-intensifying debate on climate change and how the European Union (EU) should respond to it, some of the fine print often gets overlooked. Case in point: the EU's Fuel Quality Directive, which requires a reduction of the greenhouse gas (GHG) intensity of transport fuels by at least 6% in 2020.

While most of the headlines focus on long-term environmental legislation, this directive actually should already be making a major impact on transport emissions and help achieve EU climate change goals. But according to new data from the European Environment Agency (EEA), there's still a lot of work to do.

Across the EU, fuel suppliers are not sufficiently reducing the GHG intensity of fuels, the EEA report shows. This is yet another signal that, as Member States struggle to meet their climate and renewables targets, more of them could take advantage of the Fuel Quality Directive to promote low-carbon solutions such as renewable ethanol.

The report looks at data from 2017 as reported in 2018 by 22 EU Member States. It shows that while the average GHG intensity of fuels is 3.4% lower than it was in 2010, that performance fell short of the 2017 indicative target of 4%, and risks not meeting the 2020 binding target of 6%. The projected reduction in 2020 is 4.7%, assuming a constant reduction rate.

In fact, only four EU Member States met the 4% indicative level in 2017 and only one – Sweden, where biofuels are a high policy priority – has already exceeded the 6% target. As the EEA report makes clear, an additional 2.6% reduction is needed on average in the EU.

The EEA report confirms there is clearly room for improvement in fuel quality when it comes to petrol. Member States should use the encouragement offered by the Fuel Quality Directive to lower emissions by rolling out E10, a petrol blend containing up to 10% ethanol that works in today's car fleet.

E10 is proving popular among many EU Member States as a decarbonisation move: nine of them have already adopted it (most recently the Netherlands, in October) and at least another three (Slovakia, Hungary and Lithuania) have decided to start in 2020.

Renewable ethanol reduces emissions by more than 71% on average compared to fossil petrol. In 2017, 71.9% of petrol fuel sold in the EU had up to 5% ethanol content by volume, and 15.7% had up to 10% ethanol content.

As the EU increases its ambitions for emissions reduction via the European Commission's promised Green Deal, it should leverage all the tools it has available. That includes the Fuel Quality Directive, which goes beyond what kind of cars people drive and calls for improving the fuels people put in them. This approach would make the benefits of the Green Deal start paying off in the existing car fleet, and also in the vehicles that will dominate the market for decades to come.

The role of global insurance and reinsurance capital in ensuring liquidity in new biofuels markets

Cap and trade

The best climate policy – environmentally and economically – limits emissions and puts a price on them. Cap and trade is one way to do both. It's a system designed to reduce pollution in our atmosphere. The cap on greenhouse gas (GHG) emissions that drive global warming is a firm limit on pollution. The cap gets stricter over time. The trade part is a market for companies to buy and sell allowances that let them emit only a certain amount, as supply and demand set the price. Trading gives companies an incentive to save money by cutting emissions in the most cost-effective ways. Companies that cut their pollution faster can sell allowances to companies that pollute more, or "bank" them for future use. This market – the "trade" part of cap and trade – gives companies flexibility. It increases the pool of available capital to make reductions, encourages companies to cut pollution faster and rewards innovation.

In the European Union's Emissions Trading System, capped emissions from stationary structures were 26% lower in 2016 than when the programme started in 2005. In the US, California's climate policies have led to a steady decline of the state's carbon dioxide pollution. The centrepiece is the cap and trade programme, and California's emissions from sources subject to the cap declined 8.8% between the programme's launch in 2013 and 2016. Meanwhile, the state's economy is thriving. Cap and trade makes even deeper cuts possible when countries cooperate, such as the US and Canada. California and Quebec connected their systems in 2014, building a strong market that shows great potential.

Trading in the climate finance market – the systems designed to reduce GHG emissions – sometimes creates areas of uncertainty. The risk of invalidation of credits worries market participants, but insurance risk capital can be used to mitigate these concerns and in fact already works successfully in several markets. One example of this is in the California cap and trade programme, where "buyer liability" has created a price differential between carbon offsets depending on the level of risk associated with them. By removing this risk from both offset buyers (typically refineries and utilities) and sellers (project developers), insurance adds certainty and therefore liquidity to the market because it's a guarantee with investment-grade A+ security.

As of January 2019, similar insurance coverage is now being offered to Renewable Identification Number (RIN) buyers and sellers. "Platinum-RIN" is a risk-free credit that can be bought by any market participants and applied to any RIN type. It can complement QRINs [RINs verified by the Quality Assurance Program (QAP)] by removing the residual risk or it can wrap non-Q RINs. It also can remove the need for expensive in-house procurement protocols.

The highly publicised fraud cases have created a continued wariness in the RIN market that, combined with the Environmental Protection Agency's (EPA) "buyer beware" approach – which holds obligated parties liable for invalid credits – has led some credit buyers to deal only with long-standing and trusted sellers. And that has worked to reduce liquidity in RINs trading and put smaller renewable fuel producers at a disadvantage.

Insurance is a solution that can allow market participants to buy RINs free of any fraud and invalidation risk. And that should help inject more liquidity into RIN trade because if you are holding one of those credits and it's invalidated, your investment is worthless, and worse still it exposes the compliance entity to civil fines and penalties. Insurance can take that risk away. In the RIN market, many refiners simply don't want to do business with smaller biofuel producers without pretty solid assurances that the credits are valid.

While the EPA attempted to address the issue of bogus RINs in 2014, when it established QAP (which allows for third-party validation of credits), the market use of the programme has been limited, because the process can be expensive and it does not fully remove the risk. As a result, many parties have opted instead to trade only with well-known parties, implement their own verification programmes, or buy only ethanol RINs. However, managing an in-house verification programme requires significant management time and expertise. Further, it can enable biofuel producers to increase the number of buyers to whom they can sell and permit marketers that assume RIN invalidation risk in sales contracts to offer clear title. For obligated parties like refiners, the insurance can support their due diligence programme – a "belt and braces" approach – at a relatively small additional expense.

The cost of the insurance varies depending on the category of RIN; for example, 2% of the credit value for D6 RIN (1.5% for Q-D6) and as much as 4% for a D4 RIN (2% for a Q-D4). All of the EPA's documented cases of RINs fraud have involved D4 or biomass-based diesel credits.

In addition, insurance for California's Low Carbon Fuel Standard (LCFS) programme can also be purchased, although the extent of liability for invalidated credits is still "fuzzy." But that may be changing. The California Air Resources Board didn't want to be seen coming out of the gate with a punitive LCFS programme, but that is starting to tighten up now as regulatory changes made in 2018 started to bring more clarity to who is liable for bad credits.

But the role of insurance in the Climate Finance Market isn't limited to the risk of invalidation and revocation. Buyers of RINs and LCFS credits often look for a "reg out" clause – they want to be able to cancel their purchases of RINs if the RFS or LCFS is repealed: the fear of buyers that the programmes will not be in place when credits are delivered to them, leaving a worthless commodity at a later date; and the seller being unable to represent their cash flows as dependable, and a lower likelihood of raising the debt capital needed to build out projects. Consequently, we have created a pool of insurance capital that underwrites the continued existence of the RFS and LCFS markets.

Although risks often act as barriers to investment in innovative changes in commerce, it takes the huge pool of global insurance and reinsurance capital that has traditionally taken the risks that other forms of capital (debt and equity) can't or won't take, to ensure liquidity in new markets and to finance the risks of the future. ●

For more information:
This article was written by Mike Newman, director of Parhelion Underwriting. Visit: www.parhelion.co.uk

US policy instability blamed for damaging North American biodiesel producers

A bleak outlook for biodiesel?

by Colin Ley

Politics continue to dominate the development of the biodiesel industry in North America, and not in a good way.

You can't have a year when at least 10 biodiesel producers decide to close their operations due to policy instability and reach any other conclusion than that the industry is in a mess. That's despite the fact that with a bit of US Government understanding and fair treatment, the future for biodiesel producers and consumers could be absolutely on the rise.

The big area of industry/government dispute concerns the current US administration's approach to the Renewable Fuel Standard (RFS) and the hugely confused situation that has been created around the use (or not) of biodiesel tax credits. That is what is driving the decline in production numbers at a time when everything should really be moving in the other direction.

Paul Winters, director of public affairs and federal communications at the US-based National Biodiesel Board (NBB) takes up the story: "The US industry would like to continue growing and expanding the domestic biodiesel market, inclusive of renewable diesel and heating oil. In fact, the industry would like to double in size over the next decade to stand on its own, that's the potential we have."

Unfortunately, according to the NBB, US federal policies, designed to 'support' the US biodiesel industry, have become 'unstable over the past three years'.

"The RFS sets the US market for biodiesel and renewable diesel," states Winters. "However, since 2017, the Environmental Protection Agency (EPA), which is charged with implementing the programme, has been undermining the programme by handing out small refinery exemptions to everyone that asks.

"EPA is therefore protecting nearly as much market space for petroleum gasoline and diesel through these exemptions as they are opening up for renewable fuels."

Although the agency has finally acknowledged that it is failing to ensure that renewable fuel volume standards are met, there is still much to be done to reverse the losses of the past year. While the EPA is now proposing one simple method for accounting for future small refinery exemptions, there is certainly more to do.

"The US biodiesel tax credit expired at the end of December 2017," explains Winters. "To all intents and purposes, it was actually 'expired' throughout 2017, but then retroactively granted for that year in February 2018. In that context, it was expired as soon as it was renewed."

In reality, therefore, the credit has been expired for nearly two years, which is the longest lapse the industry has had to endure since the credit was first established.

The industry, of course, takes account of the tax credit when setting sales contracts, financing agreements and the laying out of longer-term business plans. As such, the long-lasting lapse is forcing everyone to behave as though the credit hasn't expired, resulting in some US biodiesel producers financing upgrades and production expansions while actually selling fuel at a loss.

Not surprisingly, some producers decided this year that they simply couldn't continue with such practices, taking reluctant decisions to put new investments on hold, slowing down existing production, decreasing feedstock purchases and laying off workers.

"This type of slowdown is difficult to recover from," says Winters, adding that the industry will take time to ramp up production

again. And that's if the tax credit is reinstated, of course, and the RFS is stabilised – neither of which is guaranteed at this stage.

Better at state level

The picture is much brighter at state level, where local leaders, delivering much more helpful local policies, are still successfully managing to create incentives for biodiesel producers to grow and develop.

"Several states are still supportive of the US industry," says Winters. "California's Low Carbon Fuel Standard, for example, is expected to drive demand for nearly two billion gallons of biodiesel and renewable diesel over the next few years.

"New York is also setting standards for heating oil and road fuel that will increase demand for biodiesel and renewable diesel.

"Minnesota, similarly, has a strong biodiesel mandate, while both Illinois and Iowa have supportive tax policies that are driving use in the Midwest."

Shutdowns

Meanwhile, in non-supportive states, 2019 plant shutdown decisions are a clear reflection of the divide between federal-driven negatives for producers and the state-driven positives that focus on investment and progress.

One company caught in this scenario is Boston-based World Energy, which announced three biodiesel shutdowns in August this year, blaming each on the latest round of refinery exemptions. The plants in question are located in Mississippi, Georgia and Pennsylvania.

At the same time, however, the company made it clear that 'normal operations' will continue at World Energy's refineries in Hamilton, Ontario; Houston, Texas; and Paramount, California.

The idea of pursuing 'business as normal' in California, of course, rather understates what World Energy is actually seeking to achieve in the renewables-supportive state, having announced a $350 million (€317.5 million) upgrade of its Paramount operation in 2018.

Designed as a two-year project, this massive commitment to the future of California's renewables vision centres on transforming the Paramount facility into the state's 'most important hub' for the production and blending of advanced renewable fuels.

"This has obviously been a very tough year for our company with our three shutdowns being announced immediately after the early August decision by the EPA to grant another 31 small refinery waivers from the RFS," Scott Lewis, executive vice-president of commercial operations and strategy at World Energy, told *Biofuels International*.

"We could only see the market getting more injured by the decision and decided to be prudent rather than stubborn concerning the closures. You have to look further down the curve. If the EPA changes its position in the future, then we would certainly consider reopening the three plants."

For the time being, however, Lewis' view is that the federal approach in the US is simply 'a bit of a mess', certainly so far as doing anything to help reduce the country's carbon footprint by way of biodiesel or renewable diesel.

"We are continuing with our expansion in California, of course, where our investment will allow us to produce 300 million gallons of renewable diesel and jet fuel, compared to the 40 million gallons we have been producing to date," he adds.

"That's because our Paramount plant is in the right jurisdiction, producing the right product from the right feedstock and will, as a result, create a great reduction in carbon intensity."

As such, because of its supportive policies and approach, California is attracting investment from many companies. Other states, in contrast, that persist in adopting a federal-based weak RFS, are not attractive to investors. It really is as simple as that.

Canada and clean fuel

Being located in Toronto with World Energy, Lewis is well-placed to compare and contrast the mood of the industry in Canada with that in the US. It's a contrast that could hardly be starker, given the imminent introduction in Canada of a new Clean Fuel Standard (CFS), backed 100% by the Federal Government and compiled in full consultation with the industry itself.

"Industry representatives and government officials in Canada have been working to produce the new CFS for around the last two years," says Lewis.

It had been hoped the policy would have been in place ahead of the recent election, which resulted, of course, in the Liberal administration retaining control, but having to move from a majority to a minority position. Although the election came before the CFS was ready, raising some fears it might fall at the final hurdle, the new standard is now close to being released, complete with a new measurement tool for greenhouse gas emissions.

"We've not seen the rules yet, but already know there will be a carbon intensity component to it," explains Lewis. "That will be a big help, and an essential development, always provided the standard is written up correctly.

"The drive for progress in terms of carbon intensity is where we need to go as an industry; that has to be our next evolution. Just because renewable fuels are sourced from something that grows doesn't necessarily address the carbon footprint of the actual fuel that is produced."

His argument is that unless the industry takes carbon footprint into account when producing fuels, we could end up with products that are completely renewable, but which we actually don't like from a climate change perspective. In a worst-case scenario, we could even have renewable products with a carbon footprint that is not significantly better than petroleum.

"Hopefully, the new CFS will deliver on carbon intensity and do so in a way that has genuine transparency and attracts renewable fuels with the lowest carbon intensity," he adds.

Market matters

However, for all the positive and supportive action taken by Canada's government, the big North American market for biodiesel will always be dominated by the US, purely on market size and consumer demand.

With that, it's back to the depressing fact that biodiesel production has been in decline in the US since the mid-point of this year. That's in the face of a combined US market for biodiesel, renewable diesel and renewable heating oil that is continuing to grow, increasing by 180 million gallons in the first nine months of 2019, compared to the same period of 2018.

It's an increase that isn't consistent across types of fuels, however, with renewable diesel production having nearly doubled so far this year, while biodiesel production went into decline in June, after starting the year pretty strongly.

Unfortunately, as the actions of 10 different biodiesel producers have shown this year, policy instability in the US is proving successful only in driving North American biodiesel numbers down. ●

With no end in sight for market expansion, advanced hydrotreated vegetable oil will have to make up a larger share of the total

Europe's HVO feedstock conundrum

Aided by rapidly increasing biofuel mandates and physical limits to FAME blending, demand for hydrotreated vegetable oil (HVO) in Europe is booming. Neste has long had a near-monopoly on its production, but new players are rapidly entering the market. With European Union (EU) regulations imposing restrictions on palm oil and other first-generation feedstocks, sourcing of advanced feedstocks will play a defining role in who gains the competitive edge.

Demand increase

Whereas biomass-based diesel represented only 4.2 vol% of the total EU gasoil pool in 2015, this had gone up to 4.9 vol% by 2018 – with three countries reaching more than 7 vol% that year. For the 13 EU countries that have volumetric biomass-based diesel blending obligations, average mandates have increased further since; from 6.5 vol% in 2018 to 6.9 vol% in 2019, set to rise to 8.0% in 2020. In Germany and Sweden, where biofuel blending is stimulated through minimum emission reduction obligations, targets rise strongly through 2020 as well. Although some of these higher mandates are countered by double-counting of second-generation feedstocks, Stratas Advisors expects at least six northern European countries to be blending more than 7 vol% by 2020 – with outlier Sweden hitting 30 vol%.

FAME blending starts to become problematic around 5-7 vol% in northern European climates, depending on which feedstocks are used. For any volumes above this threshold, renewable diesel (HVO) is needed because its fuel properties are closer to those of petroleum diesel. Consequently, European demand for this fuel has boomed in recent years, from about 1,800 thousand tonnes (KT) in 2015 to more than 3,000KT by 2019. Despite a binding share of renewable energy in transport (RES-T) target of 14 cal% by 2030 under REDII – the revised Renewable Energy Directive – HVO growth is projected to slow down somewhat after 2020, due to declining road diesel demand and a larger proportion of the targets being met through double-counted waste-based biofuels or quadruple-counted renewable electricity. Countries like France are likely to see their biomass-based diesel and HVO blending decrease post-2023. Yet with long-term blending obligations rising strongly in other geographies – most notably Scandinavia – Stratas expects the European HVO market to reach 4,500KT in 2030.

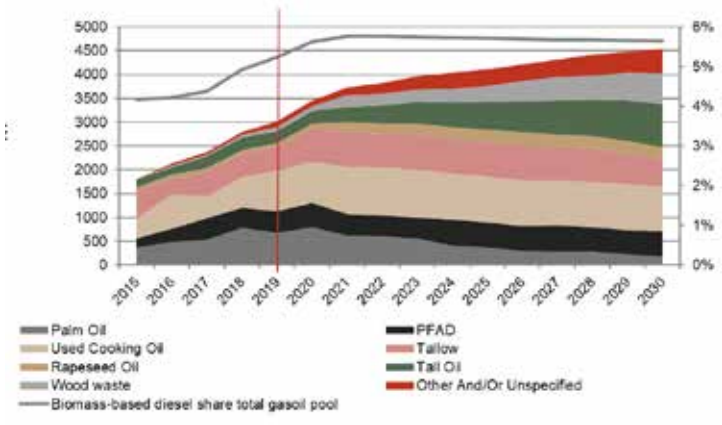


Figure 1. Annual consumption of HVO in Europe.
Source: Stratas Advisors

Capacity expansions

Traditionally, Neste has had a near-monopoly in the European HVO market. Until earlier this year, the company owned 57% of total HVO capacity (including co-processing) and 72% of stand-alone capacity. However, other refiners have taken note of the growing demand. Total, St1 and potentially OMV and PKN Orlen are entering the market, while Eni, UPM and potentially Preem are expanding their existing capacity. By 2021, only a third of the total nearly four million tonnes of HVO production capacity in Europe will be Neste's. As production is

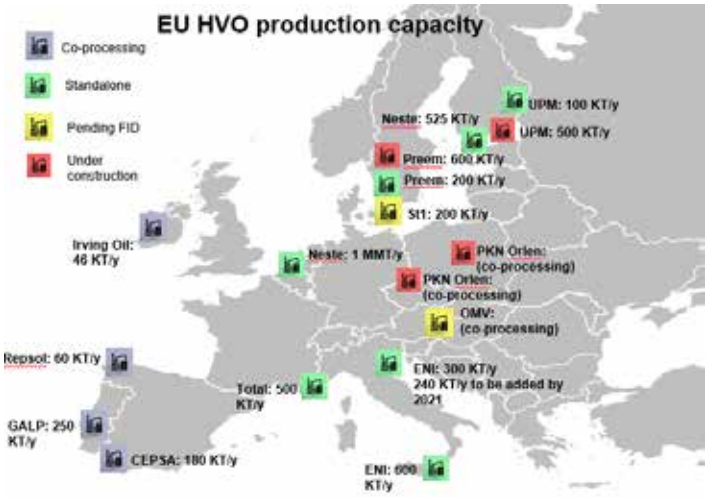


Figure 2. HVO production capacity in the EU. Source: Stratas Advisors

decentralised and stricter EU and national regulations enter into force, feedstock sourcing will play a defining role in refiners' competitiveness.

Feedstock conundrum

Crude palm oil (CPO) has historically been the most cost-effective feedstock for HVO production. Not only is CPO itself generally much cheaper than other first-generation feedstocks like rapeseed or soybean oil, but HVO production costs are also driven down because less hydrogen is needed in the hydrotreatment process, due to CPO's high content of saturated fats, and because its quality is more consistent than waste-based feedstocks, for example. However, legislation stemming from sustainability concerns is increasingly restricting palm oil as a feedstock. Earlier this year, the European Commission decided that consumption of palm oil-based biofuels will be capped at 2019 levels and phased out between 2024 and 2030 (although some exemptions are included for smallholder farmers and CPO produced on formerly abandoned land). Individual Member States are often not waiting until 2024 to restrict palm oil consumption. In Sweden, the introduction of an emission reduction-based blending obligation last year effectively rendered palm fatty acid distillate (PFAD) uneconomic in low blends due to the low emission reduction value Swedish policymakers attributed to it. French policymakers passed a law that will withdraw all fiscal support to palm oil-based biofuels from 1 January 2020, while parliaments in Norway and the Netherlands have called for similar measures. For these reasons, we expect CPO volumes used for HVO production to decline from 2020-2030.

Because of its low saturated fat content and limited local supply, soybean oil has never really been competitive in Europe as an HVO feedstock. Rapeseed oil is generally also less lucrative than palm oil due to the higher hydrogen requirement. However, its abundant local availability and seasonality in its price have made it competitive at times, with HVO from rapeseed consistently being consumed in Sweden. Partly to appease local farmers, Total also pledged to process 50KT of rapeseed oil per year in its recently commissioned La Mède HVO facility in France. However, the most prominent single-counted feedstock apart from CPO is PFAD, a by-product of palm oil processing. Its low price, favourable chemical properties and waste product status (under EU law) have made it a popular feedstock for HVO production. There are limits to PFAD supply as it represents only about 4% of the content of crude oil palm, and it has been effectively rendered uneconomic in Sweden due to the high emission value attributed to it. Nevertheless, PFAD looks largely sheltered from the palm oil storm, and significant volumes are expected to be consumed in European HVO through 2030.

Used cooking oil (UCO) and animal fats have become much sought-after HVO (and FAME) feedstocks, aided by the fact that they can be double-counted towards RED and REDII targets. Despite the fact that 80% of UCO in European restaurants is collected, local supply cannot keep up with demand; over one million tonnes of the feedstock is imported into the EU annually. More than 20% of these imports come from the US, and another 35% from China. Given rapidly growing HVO production in the US, however, the country is not expected to be a net UCO exporter for much longer. What's more, US HVO producers might even start competing with European competitors for Chinese UCO, while Neste's additional capacity in Singapore is also likely to absorb additional volumes of Chinese UCO. Recent scandals in the Netherlands and the UK, whereby CPO was fraudulently declared as UCO to gain more credits, has brought the feedstock under public scrutiny. Biofuels from animal fats face many of the same issues as UCO, and imports are further constrained by EU sanitation laws and competition with other sectors. Moreover, REDII stipulates that biofuels from UCO and animal fats together can only count towards up to 1.7 cal% (or 0.85 cal% corrected for double-counting) of total motor fuel demand by 2030. Given these constraints, Stratas Advisors expects only limited growth for these feedstocks.

REDII has a binding sub-target for advanced biofuels, which can also be double-counted. The mandate starts at 0.1 cal% of the total transport gasoil pool in 2022, going up to 0.5 cal% by 2025 and 1.75 cal% by 2030. To date, tall oil, a by-product of the paper industry, has been most successful in scaling up, and is currently used for HVO production by UPM in Finland and Preem in Sweden. With global potential supply estimated at 2.6 million tonnes, only about one-tenth of that is currently used for biofuel production. With much of the supply located close to big HVO consumers in northern Europe, the share of this feedstock is projected to grow further. Consumption of wood-based HVO, which includes sawdust, could get a boost from emerging technologies like fast pyrolysis. Other feedstocks that qualify as advanced but have hitherto only been consumed in small volumes include algae, palm oil mill effluent, empty palm fruit bunches and other non-food cellulosic material.

With no end in sight for the European HVO market's expansion and feedstock regulations tightening, advanced HVO will have to make up a larger share of the total. Some room for growth remains for UCO, tallow and PFAD. Given that the European Commission can add (though not remove) advanced feedstocks to the list, and emerging technologies could start scaling up, an increase is projected in the 'others' category as well. However, Stratas Advisors expects most growth in tall oil and wood waste HVO, with commercial plants already proven successful and most of the supply located close to major growth markets. ●

For more information:
This article was written by Cornelius Claeys and Marijn van der Wal, fuel and transport analysts at Stratas Advisors. Visit: www.stratasadvisors.com

Consumer affordability of a high(er) percentage biofuels blend

Counting the costs

The concept of blending product to create biofuels is not new. In the 1820s in the US, whale oil for fuel lamps was expensive, so a blend of camphene and alcohol was mixed and successfully used as a cheaper alternative. Farmers began to make their own stills using crop waste and soon, 100 million gallons per year were produced. The process of blending fuels continued throughout the 19th and 20th centuries and by 2005, the US had become the world's largest producer of ethanol.

In Europe, biofuels also have a long history: in the 1860s, Germany was the first country to pioneer their use, with early combustion engine prototypes designed to run on ethanol. In the UK, grain alcohol was mixed with petrol to provide an alternative fuel source during the Second World War. More recently, biofuels mandates were introduced in the US with the Renewable Fuel Standard (RFS) programme in 2006, which fostered the use of ethanol and biodiesel. Since then, the obligations have been creeping upwards, but have only recently become a major consideration for the consumer at the pump. A more significant hike upwards has come since the shift to the European Union's (EU) revised Renewable Energy Directive (REDII) where there's a split between first-generation (ethanol and bioproducts like fatty acid methyl esters, or FAME, which goes into diesel) and second-generation (or advanced) biofuels like hydrogenated vegetable oil (HVO), all of which is expected to have an impact on price.

"Fuel suppliers will have to blend in more expensive, second-generation biofuel components"

Developing economic scenario

As the biofuels market has evolved, so too have the different economics that apply to conventional petrol and diesel manufactured from crude oil derivatives. Ethanol that goes into gasoline as a biofuel is generally about the same price as the gasoline it blends into. Components in biodiesels such as FAME tend to be much more expensive than basic diesel blend stock, so the greater the volume of biofuels added, the more the price of the diesel goes up.

With REDII it will become more difficult, as there will be a cap on first-generation fuels; the rest of the obligation (UK 9-10%) will have to be made up of second-generation fuels, all of which are more expensive than first-generation.

Fuel suppliers will have to blend in more expensive, second-generation biofuel components such as ethanol from non-crop feedstocks.

'Bad' biofuels

The drive to implement these blends comes from a desire to protect against 'bad' biofuels, for example biofuels that use feedstock from crop-growing land or feedstock from areas of deforestation, such as palm oil. At the same time, retaining the merchantable quality of new fuels is crucial and there's only so much FAME you can blend before a product won't meet the required standards.

This limit is 7% (according to the specification), but most suppliers blend less, because they want to ensure their fuel is of sufficient quality. When the mandates require 10% into diesel, something else must be found, for example HVO – a high quality synthetic diesel made from bio-based components – but this is expensive, at up to three times the cost of mineral diesel (see Figure 1).

Different approaches

There are three key approaches to blending, each of which have different impacts on how the fuel supplier brings the correct fuel into the market, which in turn means differing impacts on price for the consumer.

The Nordic model

Nordic countries have a mandate according to RED or REDII and much higher targets for percentage of biofuel blends. They give a duty relief on high biofuel blends, especially those using advanced, expensive fuels like HVO. However, an unintended consequence of the Nordic system is that it draws all the higher quality feedstocks into Nordic countries, thus hiking the price of high-quality feedstocks in other countries that don't have such aggressive targets. This will produce an increase in the price of fuel for the rest of Europe.

The market model

The market-driven approach is based on mandates and reports bio supply to the government or regulator, which in turn issue tradeable certificates. This splits the market – those who over-blend and those who cover their requirements by buying certificates from suppliers who over-blend. The certificate price (trade price) becomes a marker for the cost of meeting the government's biofuels obligations. One main advantage of this model is that the pricing is transparent.

The greenhouse gas reduction model

Some biofuels offer greater reduction in carbon dioxide (CO_2) emissions than others. For example, when FAME is produced from palm oil, it offers less of a carbon reduction than when made from rapeseed oil because of the impact of deforestation. There are recognised values for the CO_2 reduction/different biofuels achieved based on a holistic analysis of the full impact, including changes of land use, deforestation and other sustainability criteria. In Germany, the mandates are set around which biofuels qualify for either first or second-generation biofuels, and recognise the level of CO_2 reduction they bring. On the other hand, although this is the most holistic model in terms of environmental benefits, it doesn't provide great transparency on price, which means it's open to profiteering by the most efficient players, especially if the pump price is set by the least efficient.

"Relief on the cost of supply could come from a relaxation of limits of biofuels in fuel specifications"

Protests at the pump?

It is possible that if the supplied costs of REDII-compliant fuels cause a big jump in price at the pump, then governments may consider acting to avoid a *gilet jaune*-style protest from consumers. However, there is a paradox in reducing fuel duty to incentivise higher biofuel blends when, ultimately, most would see the longer-term target as migrating to battery-powered mobility.

Relief on the cost of supply could come from a relaxation of limits on biofuels in fuel specifications. For example, increasing the cap on ethanol in gasoline from 5% to 10%, or increasing the cap on FAME from 7% to 10%. The former is already underway in many European Member States. The latter is on the wish list of many fuel suppliers, but we consider it unlikely to happen. This is in part due to quality issues, and also because it continues to support the increase in unwanted first-generation biofuel components.

An extension of the Nordic model

There is, however, a fourth consideration – creating demand for advanced diesel fuels that have a high percentage (up to 100% HVO) in the diesel blend. Fuels such as HVO are sufficiently high quality that they can be used pure as diesel, in addition to being 100% renewable. For example, every litre of fuel sold inland against a 10% bio obligation effectively provides 'cover' for 10 litres of fuel. However, as we have seen, they are much more expensive than conventional diesel fuels. The question remains as to whether the buyer of such advanced fuels is prepared to pay the full cost, or if some of the credit gained on meeting the obligation is used to subsidise the price of the high HVO blend fuel. It is a potential mitigation against the increased cost of supply fuels to meet the higher mandate, but it isn't a silver bullet, because somewhere the consumer will pay the additional cost.

At present, EU Member States are defining their approaches to REDII and suppliers are preparing. The current possible options to solve the higher blend conundrums are E10 for gasoline and HVO for diesel. But both carry additional cost, not all countries have shifted to E10, and there is expected to be a shortage of HVO in the short term until new producers emerge. When they do, the pressure may be lifted off the fuel suppliers, but the next challenge will be to find sufficient acceptable feedstock. ●

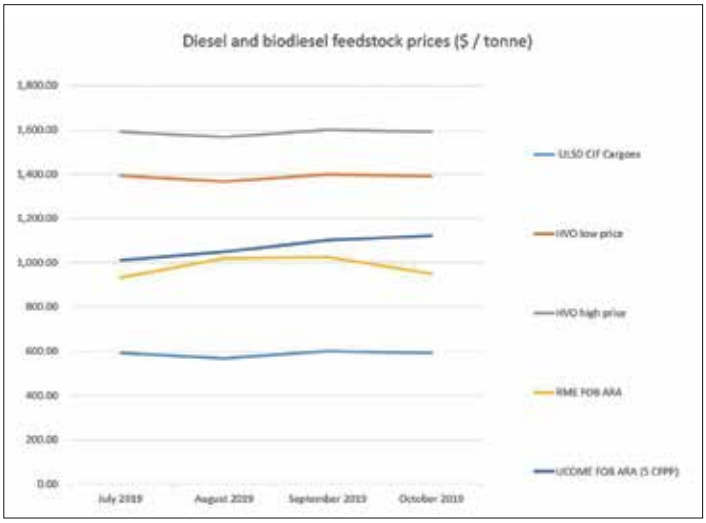
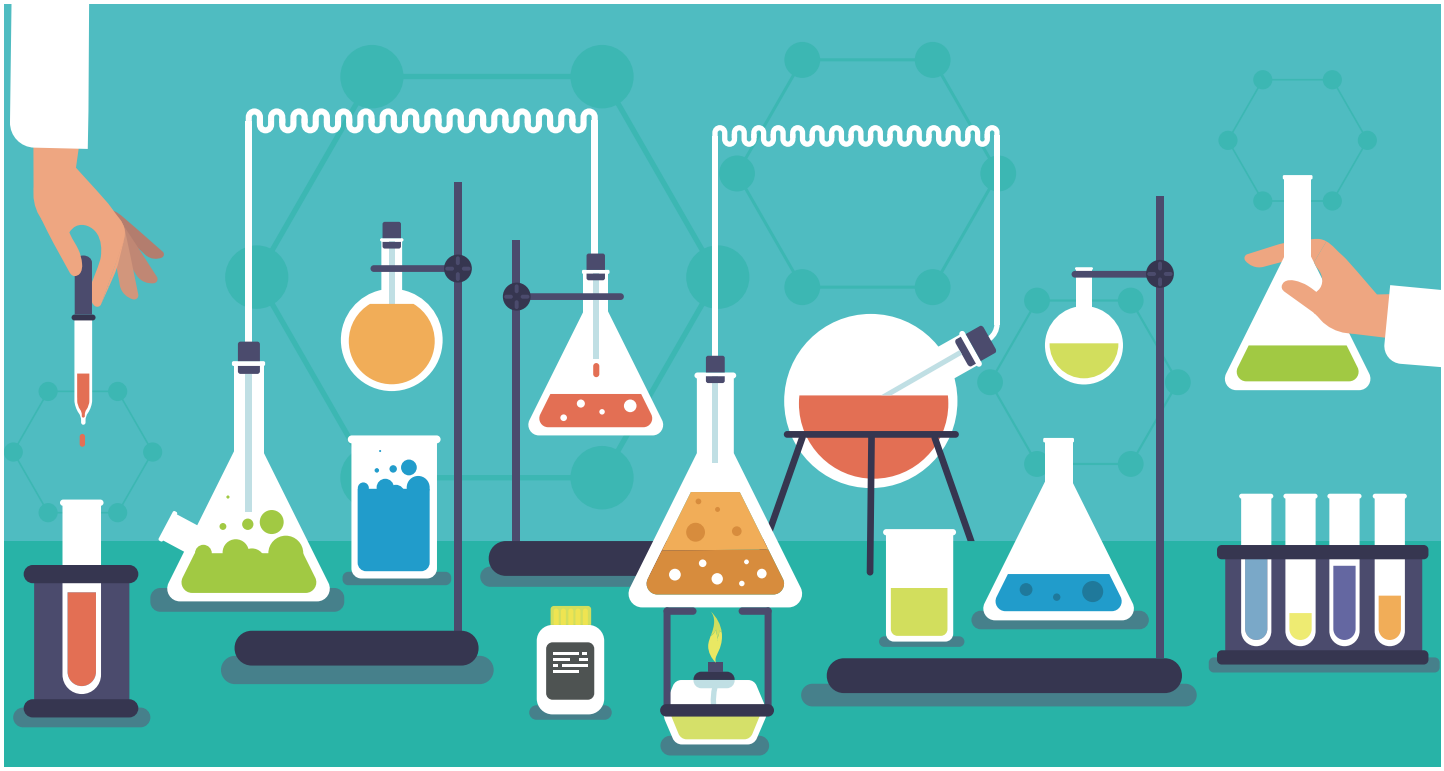


Figure 1. Diesel and biodiesel feedstock prices. Source: Prima Markets/Argus/Channoil's own sources

For more information:
This article was written by Mark Waddington, associate director at Channoil Consulting.
Visit: www.channoil.com

Europe's first industrial plant using acid catalysis is now fully on stream at Tecosol's biodiesel production plant in Germany



New catalyst on the block

The potential of acid-catalysed biodiesel transesterification has long been underestimated. In 1999, an in-depth investigation of acid catalysis to produce biodiesel was published by J. Van Gerpen, in the journal *Transactions of the ASAE* (Volume 42). He came to the following conclusions:

- Acid-catalysed transesterification is much slower than alkali-catalysed
- The completeness of ester formation increases with increasing acid catalyst amount
- If the water concentration is greater than 0.5%, the ester conversion may drop below 90%
- The free fatty acids in vegetable oils have a significant effect on the reaction. The water formed by the esterification inhibits further reaction.

Similar results were found by multiple researchers and it followed that the alkali-catalysed transesterification process became the favourite route to biodiesel production for industrial plants worldwide.

One might ask, can the temperature be increased to speed up the reaction? The answer is no. Above 60-70°C, sulphuric acid adds irreversibly to the unsaturated fatty acids. Biodiesel contains high sulphur levels that are not compatible with international fuel specifications.

The alkali-catalysed route became state-of-the-art technology. Almost all biodiesel plants worldwide run on basic catalysis, using different alkali chemicals.

Dr. Axel Ingendoh

However, there are several drawbacks that limit the efficiency of the alkali-catalysed process:

- Soap formation from free acid or induced by water in the reaction leads to an emulsification zone when separating biodiesel from glycerol
- The separation is long-lasting and incomplete. Biodiesel remains in the emulsification zone and is lost on total yield
- The emulsification zone has to be worked up separately to regain biodiesel and glycerol.

Many approaches have been made to avoid or reduce these difficulties by process changes or technical means. Water has to be excluded carefully and the feed oil must be of a very low free fatty acid level.

Biodiesel from waste

Biodiesel from waste oils, such as used cooking oil, soap

stock splitting oil and animal fats, are considered to be advanced biofuels. Biodiesel from waste oils is increasingly produced in Europe for blending into fossil diesel.

However, regardless of the origin of the waste oil, all contain free fatty acids (FFAs). The FFAs cannot be converted to fatty acid methyl ester (FAME). Alkali catalysts form soaps and are lost from conversion to biodiesel. Instead, pre-esterification with mainly sulphuric acid is used to convert the FFAs into FAME.

Alkali catalysis only works well with methanol. However, as methanol is of fossil origin, it should be replaced by bioethanol to increase the carbon dioxide (CO_2) recovery level. This concept, however, could not been realised, because the alkaline transesterification does not work sufficiently with ethanol.

When we at InaChem started our innovative project on acid catalysis, we first looked through many scientific publications on the issue of the acid catalyst used. None solved the chemical problem of replacing sulphuric acid. So we had to look for an alternative acid catalyst.

Common inorganic acids such as hydrochloric acid, phosphoric acid and nitrous acid didn't make sense. Finally, we checked certain sulphonic acids, of which methane sulphuric acid (MSA) proved to be the catalyst of choice. Unlike sulphuric acid, sulphonic acids are stable at high temperatures and do not deliver sulphur into the reaction. MSA is distilled stable at 160°C without any decomposition.

MSA is commercially available as a commodity product. It is a colourless and odourless liquid organic strong acid and doesn't fume like sulphuric acid. Applications include products for carwash, heavy-duty cleaning, household cleaning and galvanic uses.

It is biologically degradable according to OECD 301A and produces only CO_2 and sulphate when it degrades. It is safer to handle than sulphuric acid and much less corrosive. MSA is increasingly being used in biodiesel to replace sulphuric acid in the pre-esterification of waste oils.

The next step was to run through an in-depth laboratory research trial concept to find the optimised chemical reaction conditions in relation to product quality, technical feasibility and efficiency. Following success of the trial, in August 2009, InaChem filed a patent application to the European Patent Office: 'Method for manufacturing biodiesel by acid transesterification, and use of sulphonic acid as a catalyst in the manufacture of biodiesel'.

The patent was granted in October 2014 without any objections (EP 2 464 715). Using the method, which is called MBT-Technology – Methane Sulphonic Acid Biodiesel Transesterification Technology – MSA catalysed transesterification takes place at 120-130°C at an elevated pressure of 4-5 bar.

The phase separation is almost spontaneous; a very clear and sharp separation zone is obtained. No emulsification zone is formed between biodiesel and glycerol on work up, while loss of yield and the need to work up the emulsification zone separately is dramatically reduced.

Water content up to 2% doesn't have any influence on yield and purity. FFA content up to 5% in the feed oil are completely converted simultaneously. Fatty acid ethyl ester is formed just as well as FAME. This enables the production of a bioethanol-based biodiesel with improved CO_2 saving potential.

Some plant oils, for example sunflower oil, contain waxes, which can withstand transesterification with alkali and solidify in the FAME. Therefore, an additional winterisation step has to be introduced to the oil. Waxes are easily transesterified using MBT-Technology and winterisation can be omitted.

Moreover, steryl glycosides formed from phytohormones in the oil under alkaline conditions can solidify as fine waxy product, which clogs filters in the plant. This does not occur with MSA catalysis.

Next steps

The next step was to find an engineering company that would be interested in establishing a technical concept for an initial plant-scale production unit. When we met Ralf Tüerck, owner and CEO of REC Reliable Engineering Concepts, we were happy to find that REC was interested in this new transesterification chemistry. To transform the new process into an industrial production unit required new chemical and technological challenges to be mastered. This was achieved by REC.

The technical solution from REC, which is now available on the market, presents some important new benefits for biodiesel technology:

- The MBT-Technology works completely flexibly from raw materials quality
- With MSA, transesterification and esterification is carried out in one step and one unit
- Raffination of feed oils is not needed
- Reduction of tri-, di- and monoglycerides under DIN EN 14 214 specification limit is achieved
- Fast and clear phase separation takes place, without loss in yield
- The glycerol purification process is possible as MSA salts are more soluble in glycerol and easier to work up.

The technology is fully compatible with any existing biodiesel technology. Germany-based Tecosol has been operating a MBT-Technology unit at full capacity at its biodiesel production plant in southern Germany for over a year, delivering FAME from waste vegetable oil to DIN EN 14 214 quality.

At InaChem, we continue to work on future innovative developments and improvements of the MBT-Technology, such as continuous production of FAME. ●

For more information:
This article was written by Dr. Axel Ingendoh, founder of InaChem.
Visit: www.inachem.de

Argonne's online model helps bioenergy developers to conserve water

Water, water everywhere

Water sustainability affects many production steps along the bioenergy supply chain. When evaluating the effects of bioenergy production on water supply, it is critical that we understand how much water might be consumed, as well as the potential impacts of that water consumption at a regional level. Various factors contribute to stress on water supplies in addition to bioenergy production processes: competing demands for water to produce food, electricity, bioenergy and in urban development; population growth demanding an increased supply of water; and climate conditions that can exacerbate stresses on supply. Lower availability of water could disrupt production of energy, food and other products, and its ripple effects may be felt across various regions in multiple sectors.

Accounting for water consumption

Given these factors, how do we measure and compare water usage among different feedstocks across regions? What are the impacts of projected biomass production on local and regional water availability? The water footprint is a key metric to support analysis of water sustainability for informed decision-making.

Developed at Argonne National Laboratory since 2012, the Water Analysis Tool for Energy Resources, or WATER model, was designed to consider this very metric in supporting biofuels industry development and planning by providing an in-depth geospatial analysis of water consumption in the biofuels production supply chain. The tool can assist stakeholders and developers as they consider water sustainability in proposed projects. It also can help state and local governments estimate possible water consumption levels and their impacts on water quality.

"Tools like these keep us working toward meeting the national and global need for secure, affordable water," states Daniel Simmons, assistant secretary of the Office of Energy Efficiency and Renewable Energy (EERE), US Department of Energy (DOE).[1] It was adopted to assess water consumption impacts in six future scenarios addressed in the chapter on water consumption in DOE's 2016 Billion-Ton (BT16) Sustainability Report[2]; it also contains four BT2[3] cellulosic biomass scenarios and three historical production scenarios (1998–2008). WATER-based analyses have appeared in 22 publications to date.

The latest version (v.4, released in April 2019) contains the most updated knowledge and data available for estimated water resource usage levels for biofuels in the US. WATER offers downloadable data for hydrology (e.g., rain, surface stream, renewable groundwater), soil water storage, cropland acreages, fertiliser application, and other inputs.

WATER features

WATER inventories the following: historical water resources, including annual fresh renewable water and reclaimed water resources available to a region; land, including soil water storage and land use for major crops, grass and forest woods; climate data, including the 30-year historical climate; and production technologies for biofuels, petroleum and electricity. WATER simulates a geospatial-explicit water footprint for production pathways and regional scenarios at county, state and regional levels for the US in an online platform. It also estimates the impact of water use on regional water availability to other economic sectors under current and future scenarios.

Water is "lost" in biofuels production processes – through evapotranspiration during feedstock growth, evaporation during cooling and downstream separation in biorefineries and incorporation into products. The WATER framework quantifies water footprint (a combination of green,[4] blue[5] and gray water[6]) for major fuel production stages, which is expressed as gallons of water used per gallon of fuel type, per acre of land, and per ton of feedstock. Water footprint accounts for hydrology, climate, land use, plant growth modelling, conversion technology, energy and chemical inputs, products portfolio, and management and practices. WATER models multiple production pathways — including feedstock corn grain, corn fibre, soybean, wheat straw, corn stover, switchgrass and miscanthus, hardwood and softwood, short-rotation woody crops (willow, poplar, pine), processes of fermentation (starch, cellulosic), fast pyrolysis, gasification, transesterification and sugar-to-hydrocarbon.

To estimate the effect of biofuels production on regional freshwater resources, a set of water availability indices (WAIs) was developed in WATER. The WAI of a production scenario is calculated as the ratio of the difference between total resource supply and water consumption of the scenario to total resource supply in a geographic region, that is,

$$\frac{\textit{(Water resource supply-Water consumption)}}{\textit{(Water resource supply)}}.$$

WAIs compute the freshwater resources (rainwater, surface and

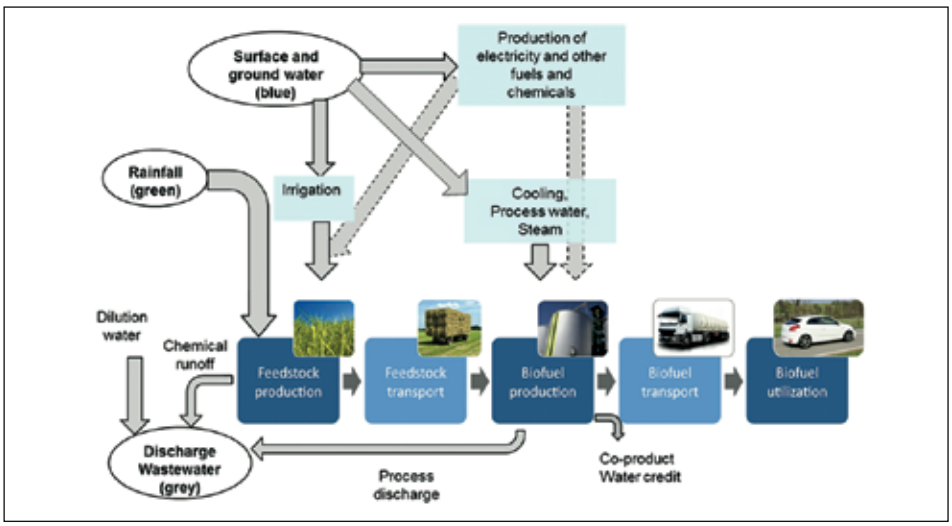


Figure 1. WATER footprint framework: water inputs and outputs in biofuels production stages

shallow groundwater) required to meet biomass production needs and remaining resources available to other economic sectors at county, state and regional scale.

WATER demonstrations

WATER is available to the public online, at https://water.es.anl.gov/. The following case studies illustrate how to use WATER to estimate the water footprint for a biorefinery, a production pathway, and for the impact of the production pathway on freshwater availability for biomass production.

Water footprint of corn grain and fibre-to-ethanol pathway, historical scenario

The water footprint of ethanol produced from corn grain (fibre is optional) via a fermentation process can be obtained using the following steps. After registering at the website, at WATER's main menu, select 'Water Footprint/Pathway Platform/Historic', which brings you to the 'Feedstock Type' tab. Select 'grain', 'county', and map types. Select 'United States' in the table, followed by 'All states in selected regions' and 'All counties in selected states', then hit 'Run'. Demo I-1 displays the water footprint results for feedstocks grown on average for the years of 1998–2008 in a map format.

Next, close the feedstock results tab and go back to main menu. Select the 'Biofuel Refinery' tab. Select 'United States' in the table, followed by 'All states in selected regions'. Select conversion process and hit 'Run'. The upper panel in Demo I-2 displays the blue water footprint (surface and groundwater) of ethanol produced from corn grain and fibre in a biorefinery by state in the bar chart.

Close the 'Biofuel Refinery' tab.

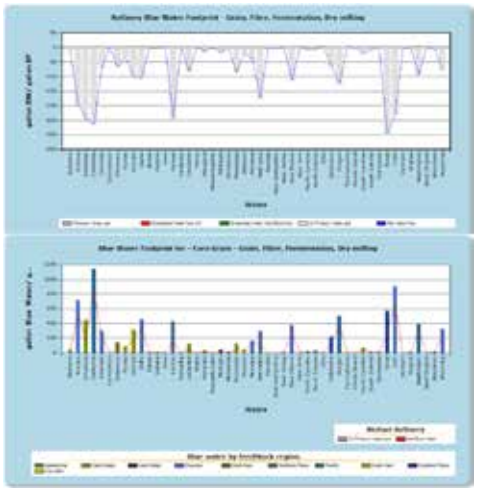


Figure 3. In Demo I-2, the upper panel shows biorefinery page output of the state-level blue water footprint for corn grain and fibre-to-ethanol pathway. A negative value shows a water credit from the co-products (i.e., distillers grains with solubles). The lower panel is part of the WATER footprint page that summarises the water footprints for blue water of the corn grain and fibre-to-ethanol pathway by state for the US

Select the 'Water Footprint' tab. The feedstock and biorefinery water use levels are summarised in this tab. Select 'default', which means that the feedstock grown in a state will supply to a biorefinery in the same state. Results of water footprints for blue, green and gray water for the pathway by state are presented. The lower panel in Demo I-2 illustrates the blue water footprint in the major lifecycle stages of this pathway.

Water availability index of biomass production

In this example, we will estimate the availability of freshwater resources to other economic sectors when demand for biomass production is met in 2008. WAIs for rainwater, stream water and shallow groundwater are determined on an annual basis and are expressed as a fraction of the total resource supply that is available to other sectors. WATER accounts for land use to grow crops for biofuel production and estimates the impact of the scenario on regional water availability.

At the main WATER menu, select 'Water Availability Index/Historic/2008', which brings you to the Water Availability Index page. Select '2008' (all feedstock) in the column at left. Select 'United States' in the table, followed by 'All states in selected regions' and 'All counties in selected states' and click 'Run'. Demo II-1 shows the WAIs for green water (rainwater) and blue water (stream and renewable groundwater), after meeting water demand for biomass, in county-level maps. ●

References:

1. Argonne National Laboratory, 2019, "Argonne releases updated computer model to help bioenergy developers conserve water," May 16, https://www.anl.gov/article/argonne-releases-updated-computer-model-to-help-bioenergy-developers-conserve-water, accessed September 3, 2019.

2. DOE, 2016, 2016 Billion-Ton Report, July, https://www.energy.gov/eere/bioenergy/2016-billion-ton-report, accessed September 3, 2019.

3. DOE, 2011, U.S. Billion-Ton Update, August, https://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf, accessed September 3, 2019.

4. Green water: soil water storage formed by rainfall and available for plant uptake.

5. Blue water: surface and ground water that can be withdrawn for irrigation and other human use.

6. Gray water: the volume of water required to dilute the chemicals to an acceptable level of concentration for the water body.

For more information:

This article was written by May Wu, principal environmental systems analyst in the Energy Systems Division at Argonne National Laboratory. Visit: https://water.es.anl.gov

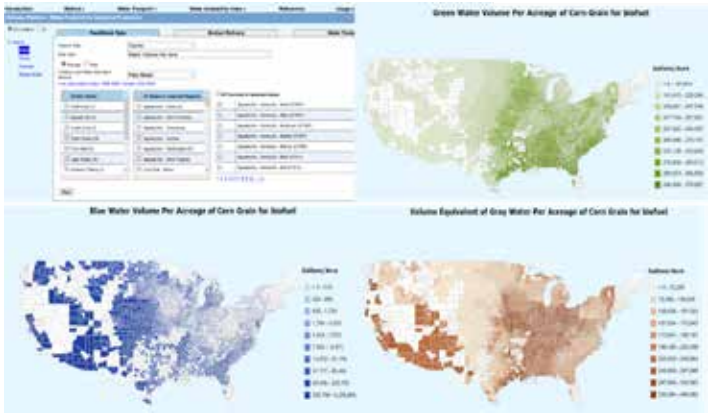


Figure 2. Demo I-1 shows feedstock page (top left) and county-level footprints for green water (top right), gray water (bottom right) and blue water (bottom left) for corn grain in the US (1998–2008 average). Assume that 30% of corn grain production on average is used for biofuels production

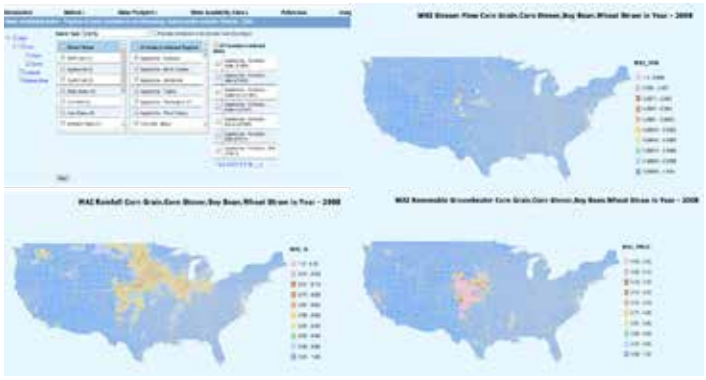


Figure 4. Demo II-1 displays the water availability index page and county-level results of the fraction of rainfall (WAI_R), stream flow (WAI_STR) and annual renewable groundwater (WAI_PRCO) resources available to other economic sectors when the water demand for biomass production is met. Large values in blue and green indicate higher levels of water availability

The challenges of working with water in ethanol plants can be minimised through the use of a dodecahedron roadmap

Working with the universal solvent

Water, known as the universal solvent, is an amazing substance. Understanding water's ability to dissolve, suspend and release both solids and gases can ensure favourable conditions in an ethanol plant. This article will present the 'Water Treater Dodecahedron', a 12-sided polygon, as a roadmap to success in meeting the numerous challenges of working with water.

Side 1: Asset protection

All plants began new at some time, representing a significant investment from the owners. From this point on, depreciation begins to erode the value of the initial investment. Water can play a pivotal role in premature failure to key equipment preventing the desired return on the initial investment. Proper monitoring and application of water treatment can extend the life expectancy of key equipment, reducing maintenance and capital replacement costs. There are many examples of boilers being in service with proper water treatment and maintenance in excess of 50 years, while normal life expectancy ranges from 10-15 years to 20-30 years. However, improper treatment can lead to rapid failure, within hours or days, resulting in blown boiler tubes and unplanned outages. Uncontrolled corrosion can lead to piping system failure that causes damage to surrounding equipment and halts fluid flow. It is easier to pipe systems new during construction than to renovate.

Side 2: Safety

Hazards lurk everywhere in the industrial environment. Pressure, temperature, corrosive, explosive, engulfment – and the list goes on. Many water treatment chemicals are relatively safe. However, the use of personal protective equipment is always required. Understand the hazards by reviewing and understanding the Safety Data Sheet. Training and experience greatly reduce the risk of injury, while shortcuts eventually lead to an accident. Take time to review procedures to protect the human capital.

Side 3: Environmental stewardship

Both clean water and clean air are ultimately necessary for survival. Understanding the impact on the environment goes beyond being a good neighbour. Take time to understand what happens to water and air released from the plant to avoid bad press, lawsuits and harm to the environment. Releasing water from the plant can lead to undesired outcomes, such as causing cancer, killing fish, or altering the ecosystem to promote algae. Examples of industrial pollution are not bound by region or time, but have become less frequent as people assume more stewardship of the environment.

Side 4: Continuous cost reduction

Plants are constantly striving to do more with less. Water influences this equation dramatically – directly with water utility and sewer costs, but also indirectly with electricity and fuel costs. Unit costs for water utility and sewer are projected to rise as ageing infrastructure must be repaired and replaced. Pre-treatment equipment such as filters, softeners and reverse osmosis should be evaluated and compared to design conditions to identify waste. Incremental operational changes tend to result in

more waste. As an example, a water softener was designed to produce soft water for 150,000 gallons of continuous service before requiring regeneration. Operators begin to observe hardness breakthrough at 145,000 gallons. To prevent the hardness from causing issues with scale, the softener service is reduced to 145,000 gallons. This results in an increase in water, sewer and salt usage for softener regeneration.

Optimal use of water for cooling is determined by temperature, solids saturation and corrosion potential. Once-through cooling is the least efficient use of water. Recirculating water, via a closed loop or open system, such as a cooling tower, increases the efficiency by recycling water and relying on thermodynamics. In an open recirculating system, pure water evaporation must be replenished with make-up water. This results in a continuous increase of total dissolved solids and the eventual need for waste known as blowdown. This mathematical relationship is generally referred to as cycles of concentration, and is expressed by [Make-up = Evaporation + Blowdown] and [Cycles of Concentration = Make-up / Blowdown]. The goal is to operate at the highest cycles of concentration without experiencing the consequences of scale and corrosion, since less water is consumed at higher cycles of concentration. For example, a cooling system operated at four cycles of concentration requires 25% blowdown. The same system operated at three cycles of concentration requires 33% blowdown, which requires more water for make-up and sewer.

Electricity is wasted by pumps when excessive backpressure is created either by scale and deposits in piping or when excessive corrosion is present, also restricting flow. Fuel is wasted for boiler operation when excess blowdown is required, or if condensate return is less than ideal.

Side 5: Plant efficiency

Water treatment has a significant influence on heat transfer and thermodynamics, which can also influence plant efficiency. The nature of scale and deposition makes heat transfer more difficult. As a result, heating or cooling processes become more difficult. This may result in loss of plant productivity, since operating capacity is lost. Design engineers typically oversize equipment to handle some loss of heat transfer efficiency. Periodic monitoring of the overall heat transfer coefficient is recommended on heat transfer equipment. Other factors beyond water treatment can impact heat transfer, as well as flow and air insulation.

Side 6: Cooling system scale and deposit control

This serves as one of the legs of the cooling triangle of scale, corrosion and microbiological control. This may be caused by internal or external foulants. Internal foulants result from dissolved solids that have exceeded saturation conditions forming suspended solids. There are numerous types of compounds that are capable of being formed as scale, however, the most common is calcium carbonate. External foulants come from airborne contaminants that get introduced into the cooling system in the cooling tower. Cooling towers make excellent air washers. Preventing scale and deposits in cooling systems is fundamental to water treatment.

Side 7: Cooling system corrosion control

There are different and complex mechanisms of corrosion. This natural process effectively converts refined metals to a more chemically stable form, such as oxides, hydroxides or sulphides. Preventing corrosion in cooling systems is also fundamental to water treatment and should be closely monitored.

Side 8: Cooling system microbiological control

Microbial control in cooling systems consists of maintaining control over algae, fungi and the multiple species of bacteria found in water systems. Pesticides or biocides are added to directly kill or control the growth of algae, fungi or bacteria. These living organisms can promote both scale and corrosion issues, in addition to posing health concerns such as Legionella.

Side 9: Boiler system scale and deposit control

Scale and deposit control are necessary in the pre-boiler, boiler, steam and condensate sub-systems. Proper operation of mechanical pre-treatment, such as softening or reverse osmosis, eliminates the majority of scale and deposit concerns. Boiler failures can occur quite rapidly when mechanical pre-treatment equipment is bypassed or not operating properly.

Side 10: Boiler system corrosion control

Corrosion control is also necessary in the pre-boiler, boiler, steam and condensate sub-systems. Corrosion generally results from oxygen pitting or carbonic acid attack resulting, as carbon dioxide created during the thermal breakdown of alkalinity in the boiler combines with condensate. Corrosion can lead to premature failure in piping and increased boiler tube complex iron deposits.

Side 11: Boiler system carryover prevention

Boiler carryover occurs when boiler water leaves the boiler with the steam. Many systems have steam separators to help reduce this phenomenon. Boiler carryover can result by mechanical means, such as level control failures, or chemical means, such as boiler water excessive total dissolved solids. Regardless of the cause, the carryover diminishes the energy of the produced steam and can lead to process contamination.

Side 12: Wastewater treatment

Sometimes water is used to work in the process or for cleaning. This water may get removed from the plant as waste. Prior to discharge, the water is treated to remove some or all pollutants. Removal is monitored by measuring an effluent key parameter, such as pH, total suspended solids or chemical oxygen demand. Success in wastewater treatment is accomplished by operating with the lowest total cost of operation while achieving the desired results.

Conclusion

Many challenges are faced while working with the universal solvent. Diligence is required to seek potential failures and resolve them early. Some potential water-related failures can rapidly occur, while others may take years to fully realise. In both cases, the failures are generally costly, robbing the plant of productivity, efficiency and profitability. The dodecahedron can help keep the plant at peak performance. ●

For more information:
This article was written by Randy McDaniel, strategic accounts manager at Weas Engineering.
Visit: www.weasengineering.com

Exhaust gas emissions and consumption tests are showing the advantages of E10

Keeping the air cleaner with E10

On the way to net-zero greenhouse gas (GHG) emissions by 2050, the European Union (EU-28) is on track to exceed its 2020 goal to reduce GHG emissions by 20%. According to Eurostat, in 2017 GHG emissions were down by 22% compared with 1990 levels.[1] However, limiting global warming to below 2°C and curbing climate change remains a significant challenge.

The transport sector is often seen as the "problem child" of climate change. Compared to 1990, the share of GHG emissions of most sectors decreased, while emissions in the transport sector increased, from 15.1% in 1990 to 24.6% in 2017.[2] The reasons for this development are the growing vehicle stock of passenger and freight transport, as well as the tendency to purchase heavier automobiles with more powerful engines. Meanwhile, however, technology-driven improvements and the use of biofuels, such as bioethanol and biodiesel, contributed to significantly reduce kilometre-related emissions and to counteract elevated traffic-emergence. In the near future, the transport sector will still depend on liquid biofuels in the European motor vehicle fleet, which is getting older year-on-year (passenger cars are now on average approximately 11 years old[3]). In both aviation and shipping, no established alternatives to combustion engines yet exist.

It is well known that bioethanol and other biofuels have the ability to reduce GHG emissions by replacing fossil fuels. The average certified GHG emission savings of renewable fuels have increased continuously. In 2018, European bioethanol achieved a GHG emission saving of 71% compared to fossil fuels.[4] Another substantial benefit of bioethanol is its ability to reduce exhaust emissions that are harmful to both the environment and human health. Recent tests commissioned by the German Bioethanol Industry Association confirmed these advantages once again.

The tests were carried out to assess the impact of bioethanol content over fuel consumption and regulated pollutants when running with Super E5 RON 95 (E5, a blend of 5% ethanol) and Super E10 RON 95 (E10, a blend of 10% ethanol). Five vehicles, approved according to Euro 6d-Temp standards and recent engine technology, were laboratory-tested on the Worldwide harmonised Light-duty vehicles Test Cycles (WLTC) class 3b cycle.

The chosen vehicles should be representative for the mid-size, compact and subcompact vehicle class. Furthermore, the tests should be performed on vehicles with direct as well as manifold injection. Considering these aspects and taking into account the most represented passenger car types in the German car stock, the following passenger cars were selected: Ford Fiesta, Opel Corsa, VW Golf, Renault Mégane and BMW 3-series. Regarding current debates on exhaust gases, as well

Exhaust emission and fuel consumption measurements (WLTP)	**Fiesta 1.1** (1)		**Corsa 1.4** (2)		**Golf Variant 1.0 TSI** (3)		**Mégane TCE160** (4)		**318i** (5)	
Petrol type	Super (E5)	Super E10	Super (E5)	Super E10	Super (E5)	Super E10	Super (E5)	Super E10	Super (E5)	Super E10
Consumption in L/100 km	5,29	5,38	5,87	5,74	5,27	5,24	5,69	5,68	6,19	6,23
Difference in %	1,70 %		−2,21 %		−0,57 %		−0,18 %		0,65 %	
NO_x* in g/km	0,0055	0,0049	0,0509	0,0355	0,0203	0,0180	0,0128	0,0132	0,0176	0,0084
Difference in %	−9,9 %		−30,3 %		−11,3 %		3,0 %		−52,3 %	
PN*/km	$1,6 \times 10^{12}$	$4,5 \times 10^{11}$	$1,6 \times 10^{12}$	$4,4 \times 10^{11}$	$7,1 \times 10^{10}$	$3,4 \times 10^{10}$	$6,9 \times 10^{10}$	$2,5 \times 10^{10}$	$7,9 \times 10^{11}$	$2,6 \times 10^{11}$
Difference in %	−71,8 %		−72,8 %		−52,1 %		−63,5 %		−67,1 %	
Car classification	subcompact car		subcompact car		compact car		compact car		mid-size car	
Displacement in cm^3	1084		1398		999		1332		1499	
Performance in kW	52		66		81		120		100	
Engine Design	intake-manifold fuel injection		intake-manifold fuel injection		direct fuel injection with turbocharger		direct fuel injection with turbocharger		direct fuel injection with turbocharger	

Standardised exhaust emission and fuel consumption measurements in acc. with regulation (EU) 2015/1151 WLTP with test fuel Euro-6 fuel E5 and E10 (5 % and 10 % bioethanol content) in five cars with petrol engines; *NO_x: nitrogen oxides; PN: particle number

Figure 1. Standardised exhaust emission and fuel consumption measurements

as common misconceptions about a highly increased fuel consumption using E10, the main goal was to measure the influence of the bioethanol content on fuel consumption, as well as particle number and nitrogen oxides emissions. The main technical data and results are shown in Figure 1.

"In the performed tests, particle emissions, particulate number and particulate matter were measured and compared when running the test vehicles on E5 and E10"

E5 vs E10: fuel consumption

The fuel consumption of vehicles 2-4 was lower with E10 than with E5. The difference in consumption for VW Golf (3) and Renault Mégane (4) is < 1%, and can be seen as measurement uncertainty due to driver handling. In contrast, the fuel consumption in vehicles 1 and 5 is slightly higher with E10 than with E5. Therefore, it can be concluded that there is no significant difference in fuel consumption between E5 and E10. A meta-analysis carried out by the Institute for Powertrains and Automotive Technology in Vienna (2014)[5] showed that fuel consumption when using ethanol blends is, as expected, rising with the increasing share of ethanol, due to the lower heating value of the alcohol. However, the increase is lower than the theoretical fuel consumption. For E20/E25 blends the meta-analysis reports an average increase in fuel consumption of 3.1% (theory: 7.7%) compared to fossil fuel, and for E5/E10 a rise of 1.0% (theory: 2.9%). The observed fuel economy improvements of 4.6% for E20/E25 and 1.8% for E5/E10, respectively, result from the thermodynamic advantage due to the use of ethanol.

E10 lowers particle emissions

Particle emissions are caused by inhomogeneous fuel/air mixtures and fuel-wall interactions in the combustion chamber. Furthermore, their formation is strongly related to the content of aromatic compounds. The share of these high-boiling components, and hence the production of soot precursors, can be reduced with ethanol blends. The benefit of ethanol as a clean, high-octane blend shouldn't be overlooked.

In the performed tests, particle emissions, particulate number (PN) and particulate matter (PM) were measured and compared when running the test vehicles on E5 and E10. In general, it has been shown that using E10 significantly reduces particle emissions compared to E5. A reduction of PN of around 52–73 % was observed with E10. It should be mentioned that vehicles 1, 2 and 5 are only meeting the Euro-6 standard requirements when running on E10 (threshold: 6 x 10^{11} PN/km).

E10 reduces nitrogen oxides emissions

During combustion, nitrogen oxide (NO) and nitrogen dioxide (NO_2), summarised as nitrogen oxides (NO_x), are formed in large quantities. The formation of these compounds depends, among other things, on the temperature range of combustion and the stoichiometric ratio of nitrogen and oxygen in the combustion zone. Most present-day vehicles are equipped with a catalytic converter to reduce NO_x, consequently lowering air pollutants and their adverse health effects. Four of the tested vehicles (1-3, 5) showed NO_x emission reductions between 10% and 52% using E10, compared to E5. For Renault Mégane (4), emissions were slightly higher when running on E10 than on E5 (+3%).

E5 vs E10: conclusion

To get reliable results and to avoid measurement uncertainties, it is recommended to perform the tests repeatedly with E5 and E10, always using the same vehicle. However, the results of the exhaust emission and consumption tests are clearly showing the advantages of E10 over E5. ●

Figure 2: Roller dynamometer test bench used in the measurement of exhaust emissions and fuel consumption

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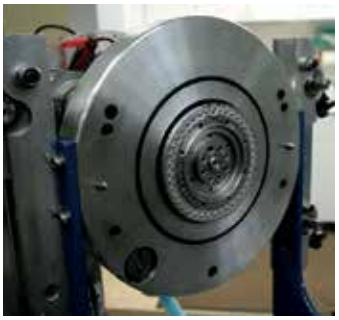
For more information:
This article was written by Dr. N. Elizarov, advisor on research and statistics at the German Bioethanol Industry Association. Visit: www.bdbe.de

Using radiocarbon dating to quantify biogenic content in biofuels

Carbon-14 for co-processed fuels

Efforts to decrease greenhouse gas (GHG) emissions drive the growing production and use of biofuel blends. Often, the percentage of biocarbon that comprises a biofuel blend must be measured. Carbon-14 analysis (radiocarbon dating) is a precise tool to determine the percentage of carbon in a biofuel that is sourced from renewable resources, as opposed to fossil sources.[1]

Innovative transportation fuel alternatives are continuously in development. This includes the production of low-carbon hydrocarbon fuels through co-processing: the simultaneous transformation of biogenic feedstocks (or low-carbon intensity non-biogenic feedstocks) and intermediate petroleum distillates in a conventional petroleum refinery.[2] Carbon-14 can determine the fraction of biogenic components within co-processed fuels or fuels produced from mixed feedstocks, which is especially useful when the measurement is a regulatory requirement.



How does carbon-14 work?

Carbon-14 testing has been employed for decades, applicable to several areas including the biofuels, bioplastics, renewables, flavour and fragrance, archaeology and geology sectors. By using the carbon-14 method to measure the biogenic carbon content, manufacturers can check the composition of biofuel blends by receiving data on the proportion of the fuel that is biomass-derived versus fossil fuel-derived.

To understand how carbon-14 testing works, it is important to note that the radioactive carbon-14 isotope is only present in material derived from biomass resources, such as plant-based or animal-based sources. Any material that comes from fossil fuel sources has no carbon-14 present.[1]

Carbon-14 isotope originates in the atmosphere and enters the food chain when absorbed by plants during photosynthesis, resulting in all living organisms containing a known level of carbon-14. Once a living organism dies, the levels of carbon-14 start to decay at a rate of approximately 5,730 years, the half-life of carbon-14. Once it has been at least 50,000 years since the death of an organism, there is no carbon-14 left.[3]

Thus, by using an accelerator mass spectrometer, the amount of carbon-14 content present in a given fuel sample can be counted.[4] This calculation is based on the ASTM D6866 standard, which determines the biobased (biogenic) carbon content of solid, liquid or gaseous samples using radiocarbon.[5]

The carbon-14 result will, therefore, indicate the presence of material from renewable versus petroleum feedstocks. Results are reported as percent biobased content, ranging from 0% to 100%, depending on the portion of biogenic carbon.

Calculation required by regulations

Recently, fuel manufacturers have co-processed bio-oil with petroleum feeds, as it is a cost-effective way to transition to the production of biofuels by utilising existing refinery processes, storage and transport infrastructure. Further, co-processing is beneficial since it may help mitigate the availability issues of biomass-derived feeds.[6]

"Any material that comes from fossil fuel sources has no carbon-14 present"

Within the fuels industry, there are regulations in place that offer incentives for the use of low-carbon fuel and, as a result, producers are aiming to decrease their carbon intensity, which is the sum of the GHG emissions emitted throughout the entire process of fuel production and use.[7]

In California, for example, the Low Carbon Fuel Standard (LCFS) aims to reduce petroleum dependency and to decrease GHG emissions through the use of cleaner low-carbon fuel alternatives. Under this regulation, carbon intensity scores are assessed for each fuel in comparison to a carbon intensity benchmark, which is declining each year. If fuels are above the carbon intensity benchmark, they will generate deficits. However, low-carbon fuels that fall below the benchmark will generate credits, creating financial incentives for manufacturers.[8] Co-processed fuels can contribute to the 10% reduction in the carbon intensity of transportation fuels required by the LCFS programme.[2,9]

Demonstrating that mixed fuels and co-processed fuels for transportation purposes meet carbon intensity standards and fall below the carbon intensity benchmark is sometimes a challenge.[8] Quantification of the biogenic carbon content of the co-processed fuels is therefore necessary. Manufacturers are viewing carbon-14 testing as a viable option as the methodology is recognised by standards such as ASTM D6866, as mentioned earlier.[6] By using carbon-14 analysis, fossil carbon can be distinguished from biocarbon components of co-processed fuels.[10]

Conclusion

In a market increasingly focused on sustainability, several factories are transitioning to the production

of mixed fuels (mixtures of biomass oil and fossil fuel-derived oil) through co-processing techniques. Co-processing acts as a means to decrease the carbon intensity of fuel. With this emerging technology, some regulations are requiring calculations of total renewable fuel used in order to determine whether or not credits can be generated. Carbon-14 testing serves as an option to provide quantitative measurements of the presence of renewable versus petroleum feedstocks.[11]

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For more information:

This article was written by Haley Gershon, marketing specialist at Beta Analytic.
Visit: www.betalabservices.com

Opening the door to biofuels research through transnational access

Breaking barriers with BRISK2

This year, for the first time since the Industrial Revolution, more of Britain's electricity production will come from zero carbon energy sources than fossil fuels, according to the National Grid. Annual power generation data from the last 10 years shows Britain's dependence on cleaner energy sources (wind, solar, nuclear, hydro power and energy storage) will surpass fossil fuels (coal- and gas-fired power generation) this year. The UK wants to achieve net zero emissions by 2050.

This is all good news. However, behind any piece of good scientific news is many years – indeed often decades – of research by determined bioenergy scientists working passionately behind the scenes on the development of biofuel production.

But what happens when a bioenergy scientist needs a piece of equipment or rig that their home institute does not have?

"BRISK2 helps biofuel researchers to share facilities across Europe"

This is where the BRISK2 research project comes in. Funded by the European Union's (EU) Horizon 2020 programme, BRISK2 helps biofuel researchers to share facilities across Europe and therefore overcome research and development obstacles. When a scientist cannot pursue a strand of research because of a lack of facilities or expertise, they can travel to a participating partner and carry out their research there, with the relevant equipment and experts.

It is called transnational access and is about breaking barriers in research.

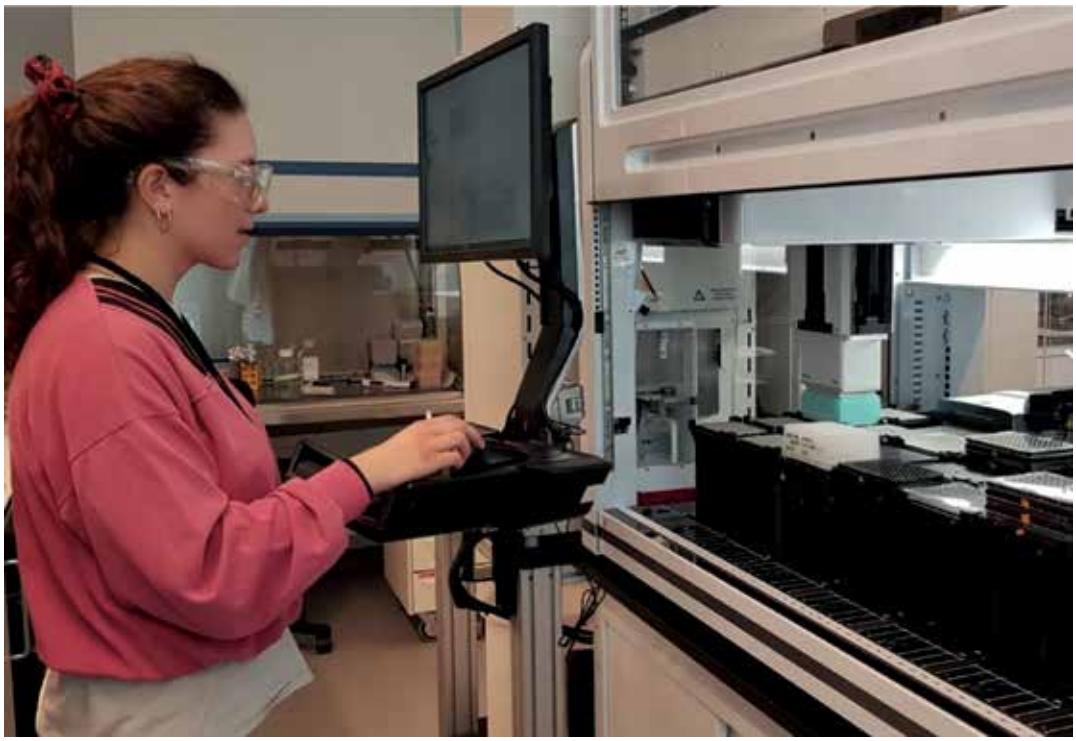
Examples of BRISK2 visits include a researcher from Denmark who went to independent research organisation SINTEF in Norway to work with a high-throughput sequencing platform their home institute did not have, enabling crucial data to be gathered. A scientist from Croatia travelled to ENEA's Trisaia Research Centre in Italy to gather data for updraft gasification that could not be produced at home. And two researchers from the Ukraine visited BIOENERGY 2020+ in Austria to examine the thermal behaviour and kinetics parameters of the combustion of sunflower husks and walnut shells. All projects achieved their goals.

In fact, since this project started in June 2017, BRISK2 has enabled over a hundred researchers to access facilities that advance their research. In all cases, the common goal has been advancing biofuel production: how efficiently and cleanly it is made, how pure and how versatile the resulting product is, how many different products can be made, and how biofuels can be made on a progressively larger scale.

This five-year project is truly international and applications to organisations within the BRISK2 network are welcome from around the world. The minimum level of qualification is a Bachelor of Science or a science engineering equivalent.

The fifteen BRISK2 partners are:

- Aston University, which has expertise in slow, intermediate and fast



Danish researcher Alba Martinez carrying out experiments at SINTEF in Norway

pyrolysis alongside biomass preparation, bio-oil upgrading, catalysis and hydrothermal processing
- KTH, Royal Institute of Technology in Stockholm. KTH has three installations for fast pyrolysis, hydrothermal processing and gasification product characterisation
- The Energy Research Centre of the Netherlands (ECN>TNO), which offers facilities for combustion, gasification, pyrolysis, tar analysis and removal alongside expertise in transitioning to sustainable energy systems
- SINTEF in Trondheim, Norway. SINTEF offers access to biomass and product characterisation and analysis, pyrolysis and pyrolysis oil upgrading, and fermentation technologies
- The Karlsruhe Institute of Technology (KIT) in Germany offers access to equipment for hydrogenation, hydrothermal processing, fast pyrolysis and pyrolysis oil hydrodeoxygenation
- BIOENERGY 2020+ in Austria, which works on the characterisation of new feedstocks for thermochemical and biochemical conversion processes
- Wageningen University in the Netherlands offers access to equipment for catalysis, biomass fractionation, pre-treatment, separation processes, screw and pressure reactors and a belt filter press
- The Centre for Research & Technology Hellas (CERTH) in Greece offers access to a fixed bed gasifier and fuel and residues analytical laboratory
- The National Renewable Energy Center of Spain (CENER) offers facilities in biomass characterisation and preparation, torrefaction, gasification, fermentation and pre-treatment

The research team at ENEA in Matera, Italy with researcher Damijan Cerinski (second from left)

- The National Laboratory of Energy and Geology (LNEG) in Lisbon, Portugal offers biomass and product characterisation, fermentation, product separation, pyrolysis, microalgae production and wastewater treatment
- ENEA, the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, offers pressure reactors for pre-treatment and fractionation, as well as technologies for hydrogen production and separation, updraft gasification and steam reforming
- TUDelft in the Netherlands offers bioresearch scientists access to biomass characterisation, pyrolysis and gasification technologies
- Politecnico di Torino, Italy offers access to equipment for biomass fractionation, biomass preparation, fermentation, fuel cells, combustion gasification and tar analysis
- VTT Technical Research Centre of Finland offers eight installations for gasification, tar reform, ash analysis, biomass characterisation, catalysis, combustion and pyrolysis
- The Graz University of Technology in Austria offers technologies in gasification, gas cleaning, tar analysis, combustion of solids and slurries and fuel cell diagnostics.

"The project is funded by the EU's Horizon 2020 research and innovation programme"

Details of rigs and facilities, as well as how to apply for funding, can be found on the BRISK2 website. The project is funded by the EU's Horizon 2020 research and innovation programme under grant agreement number 731101. ●

For more information:
Visit: www.brisk2.eu

From trash to treasure

Scientists in the US have successfully converted municipal waste into biofuel precursors

As the need for energy security grows, scientists are investigating non-food biomass sources that can be used to create valuable biofuels and bioproducts.

Among these sources is municipal solid waste (MSW) – in other words, rubbish that's produced every day around the world in significant amounts.

According to a US Department of Energy report[1], over 260 million tonnes of MSW were produced in the US in 2015. This includes food waste, yard trimmings, non-recycled paper, and more.

MSW is usually considered as a zero or negative cost feedstock. It's also versatile – MSW can be used either as a standalone feedstock, or it can be blended with other biomass.

In a collaboration between the Joint BioEnergy Institute and the Advanced Biofuels and Bioproducts Process Development Unit (ABPDU) – both established by the Department of Energy and based at Lawrence Berkeley National Laboratory – researchers converted MSW and biomass blends into valuable biofuel precursors.

The blends combined MSW items (non-recyclable paper and grass clippings) with biomass (corn stover and switchgrass). Using engineered *E. coli*, they converted these blends into methyl ketones, which are chemical compounds that can be used as diesel fuel precursors.

Their results, published in the journal *ChemSusChem*[2], are the first reported conversion of MSW to methyl ketones using an ionic liquid-based process.

Ionic liquids are a class of molten salts with a low melting point, which makes them excellent solvents. They can efficiently break down lignocellulosic biomass, but they also require costly added steps.

"The main challenge for ionic liquid application in biomass is the cost," says Berkeley Lab researcher Ning Sun, the study's corresponding author. "We have to recycle over 95% of the ionic liquid in the end."

Some ionic liquids are toxic to enzymes and microbes. The pretreated biomass has to be washed before downstream processing to remove the residual ionic liquids. The high water consumption and waste treatment requirements add to the cost and scale-up challenges.

In this study, researchers instead used bio-derived ionic liquids, which can selectively remove lignin and improve yields. These salts also have qualities that make them non-toxic and compatible with enzymes and microbes.

"Using this process, we only use 10% ionic liquid in water," adds Sun. "We reduce the ionic liquid usage, plus we don't need to wash out the ionic liquid because it's biocompatible. This represents an efficient and more environmentally friendly process for biomass upgrading."

The researchers were able to scale up one of these MSW-biomass blends 30-fold, from less than half a litre to six litres.

They then performed a techno-economic analysis to find ways to improve the process and determine its economic performance.

"Our techno-economic analysis showed that we have to improve the final product titers," Sun says. "The final product has to be comparable to the current field. In order to do that, we need to improve the performance of the microbes as well."

Researchers are currently working on scaling up this process to 600 litres at the ABPDU, a facility for testing and developing emerging biofuels and bioproduct technologies in a process demonstration production environment. Achieving this level of scale-up will further prove the process scalability.

"If we show the hydrolysate is fermentable, it's likely we can make other molecules as well," Sun explains.

Sun says municipal solid waste's role in the bioeconomy is promising, especially when it comes to removing the landfill burden. According to the US Environmental Protection Agency[3], 52.5% of MSW generated in the US in 2015 went to landfills.

"In the future, we can eliminate the landfill burden and convert this waste into useful chemicals and fuels," Sun says. "It's beneficial for the environment and we lower the cost of feedstocks for the conversion process. It's a win-win."

Using non-food sources as feedstocks can also lower the cost of biofuels and increase their availability. Though the blends used in this study contained paper waste and yard waste, food waste could be used in this process as well.

"The intermediate is sugar, and food already has a lot of free sugars," Sun adds. "Once we have non-toxic sugars, we can convert to anything, basically, depending on the microbes."

The wide range of non-food biomass feedstocks that can be used, including MSW, creates opportunities for increasing energy dependence and reducing greenhouse gas emissions.

"MSW is very promising, based on our study," Sun concludes. "This opens the door to building biorefinery facilities that use diversified feedstocks to produce a range of chemicals." ●

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This article was written by Emily Scott, public affairs specialist at Lawrence Berkeley National Laboratory. Visit: www.lbl.gov

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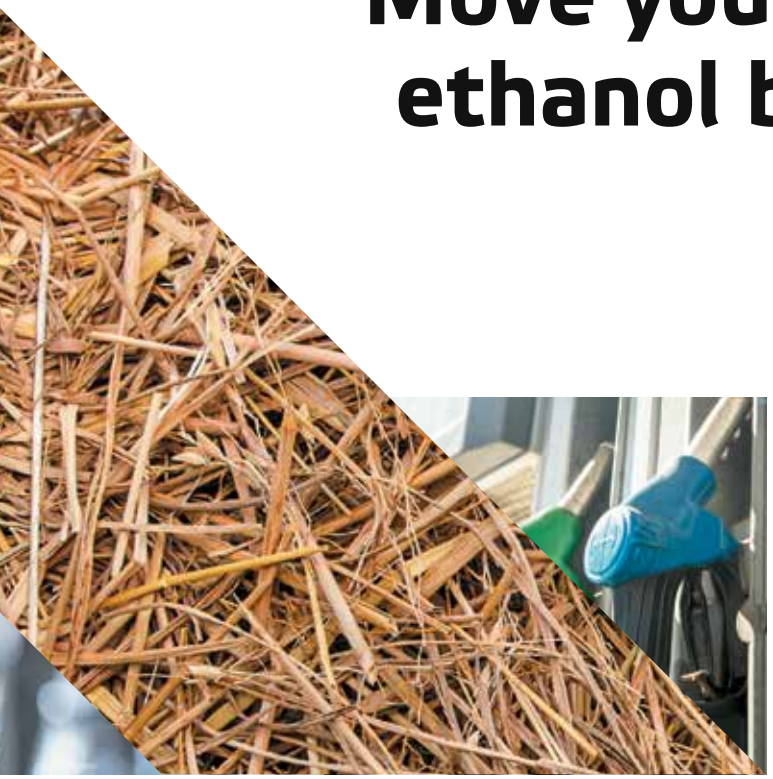

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