Exploring the various biofuel alternatives on the market to meet increasing green fuel demand

Feedstock matrix

A team from Net-Zero-Solution – a division of Channoil Energy – examined the rapid development of advanced feedstock markets covering the current regulatory environment and the impact it is having on advanced feedstock availability.

The team then looked at the matrix of feedstock types that are emerging and examined some of the new arrivals on the scene.

They then reviewed the two key biofuel production technology alternatives – biological and thermochemical – to determine if and how they compete.

Regulatory environment

Biofuels are not always price competitive against fossil fuels. So, mandates are generally required to drive their uptake. The US and Europe (EU and the UK) are the furthest ahead in setting requirements for the uptake of biofuels.

The EU under its latest release of the Renewable Energy Directive (RED II) has attempted to address some of the shortcomings to keep progressing with the decarbonisation agenda. Key to this has been:

- The introduction of the crop cap – a limit on production met by crop-based fuels
- Setting rules for the minimum contribution of advanced biofuels
- Taking steps to eliminate palm oil gradually from the fuel supply chain

Table 1 shows the targeted mix from 2030. Remembering that some of the feedstocks or energy sources count double if they are sustainable, the volume percentages in the final fuel pool will be half the percentage shown in those cases.

What is a certainty is that non-crop biofuels are now mandated to a level that requires suppliers to diversify away from dealing with (almost) everything with just two products – FAME and first-generation bioethanol.

The combination of the volume mandates, the double-counting incentives and the intricate approval mechanisms for feedstocks is helping to create a market for sustainable advanced products.

In the US, there are two sets of mandates. Firstly, the US Renewable Fuels Standard (RFS) sets minimum bio percentage quantities for the main transport fuel grades of petrol and diesel.

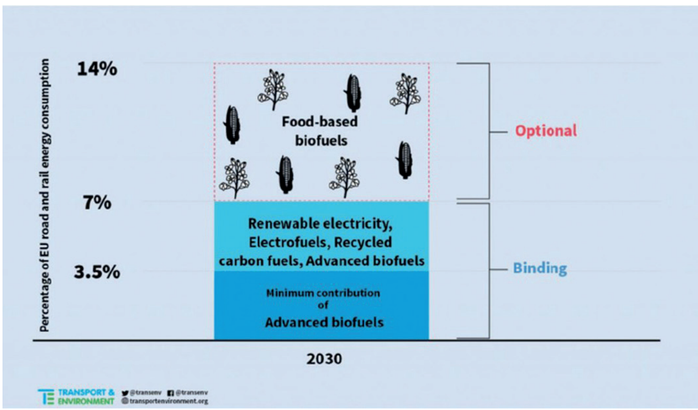

Table 1 outlines the targeted mix from 2030

California has a more nuanced approach using its own Low Carbon Fuel Standard (LCFS). This sets a specific, 'sustainability score' for every feedstock and production technology combination that is used to make a biofuel.

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These scores account for all of the well-to-wheel elements of sustainability and arguably give the most level playing field of any biofuel regulation.

Both the Californian and EU standards have been successful in incentivising the development of new production technologies and new alternative feedstocks.

The UK, which continues to parallel the EU RED II to a degree, has some stricter definitions than the EU on development fuels.

Feedstock types

Moving on to feedstock types. Here are some definitions:

- Carbohydrates – sugar and starch – these are used for traditional fermentation and distillation into ethanol.
- Secondly, lipids, or fats. These are oil-based crops such as sunflower, rapeseed and soy. Used cooking oil (UCO) and tallow are also lipids.
- Finally, cellulosic feedstocks. These are indigestible or hard process organic matter. Cellulose is the compound that gives plants their structure. Typically, it has to be broken down in two stages to make the final fuel product.

It is in the lipids and cellulosic material that producers are seeing lots of innovation in the search for advanced feedstocks. This leads us to a matrix of feedstock types.

The matrix here considers, on the one hand, the type of feedstock – carbohydrate, lipid or cellulosic, and, on the other hand, the production technology – basically either conventional or advanced. However, there is a third category called 'intermediate', which could be argued to be the 'pre-advanced' category. Another dimension is production technology.

Emerging feedstock alternatives

So, what is emerging in the world of advanced feedstocks?

Firstly, there are what you might call intercrops – or crops that are grown between harvests of food crops.

The ones in vogue at the moment are some that are from the same 'brassica' family as oilseed rape, but offering better yields in varying climates.

Carinata and Camelina are the main ones that grow readily in more temperate or cooler climates. Chufa is another crop – in this case a tuber that produces a nut with a high oil content.

The next category is advanced lipids, excluding UCO and tallow, both of which are finite resources that are also crop and food supply chain dependent. This category is about finding new feedstocks that are otherwise going to waste. It includes:

- Palm oil mill effluent (or POME). Arguably a product of inefficiency, as the more effective the milling process, the less effluent is produced. Yet thanks to the incentives around finding advanced feedstocks, and palm oil's diminishing popularity, it is now turning into an attractive source of revenue for palm oil mills
- Spent bleaching earth is another by-product of vegetable and palm oil refining. The lipids are extracted from the bleaching material and returned into a hydrolysis or biodiesel production process
- Distillate corn oil is obtained as a by-product of corn alcohol production on an industrial scale and is currently used as a raw material in the biodiesel industry
- Wastewater sludge is a by-product of the sewage treatment industry and again can be re-treated to extract the lipids that remain
- A more familiar feedstock – trapped oil – or as it is sometimes called – fatbergs – essentially a gathering of solid high fat content waste material that can be physically extracted. The lipids are then separated and re-processed into biodiesel.

Cellulosic biomass is an interesting and diverse area. Forestry waste is a source of large amounts of biomass

	Carbohydrate	Lipid	Cellulosic
Conventional	Sugar cane, sugar beet, corn starch, wheat starch…	Rapeseed oil, soybean oil, palm oil…	n/a
Intermediate (EU RED II Annex IX B)	n/a	Used cooking oil, tallow	n/a
Advanced (EU RED II Annex IX A)	Residual carbohydrates e.g. wine residues	POME, DCO*, algal oil…	Agricultural waste, forestry waste, miscanthus, energy cane, bagasse…

Table 2 outlines the various feedstock types material – it is basically the clearing of the forest floor from large-scale wood production. The question is going to be, what can be sustainably recovered without land degradation?

Then there are energy crops such as Miscanthus, energy cane and energy willow, plus others. The dilemma faced here is not land degradation, it is the land use itself, which is again potentially competing against the crop and food supply chain.

What is encouraging to note, is markets develop quickly to allow supply chains to develop these options.

All the main feedstocks trade as discrete grades and are increasingly covered by the price reporting agencies. There is no market yet for some of the exotic feedstocks, which is partly driven by availability and partly by the production technology not reaching scale yet.

There will also in some cases be no market where producers of the biofuel manage the feedstock supply chain directly.

Palm oil as a feedstock has declined in popularity

Production technology alternatives

Furl production technologies can be grouped into either biological or thermochemical processes. Biological processes such as ethanol fermentation or algae cultivation for oil are low energy intensity technologies and are, therefore, more sustainable than thermochemical processes. This generally entails the use of temperature and pressure in a reactor, possibly followed by post-treatment or distillation of the finished product.

However, thermochemical processes can also achieve a more effective functioning substitute for the fossil fuel it replaces.

Renewable diesel and sustainable aviation fuel are examples of this. These have often been discussed as competing alternatives.

However, in practice, both may be needed for technological reasons and simply to produce enough biofuel. Indeed, many advanced feedstocks will need a conversion pathway with both biological and thermochemical technology.

Conclusions

Total biofuels production is limited by feedstock availability and this will continue to drive the search for more feedstocks. This looks like a major challenge, because of large amounts of capacity coming on stream for producing hydrotreated vegetable oil and sustainable aviation fuel.

Regulatory mechanisms are needed to incentivise advanced feedstocks, otherwise the producers might turn to more readily available primary crop feedstocks.

However, these mechanisms can have unintended consequences, such as POME being worth more to a palm oil producer than running the mills more efficiently.

There is potential in new areas such as intercrops, advanced lipids, and cellulosic material; these will broaden the available feedstock pool considerably.

However, diversion of feedstocks from their alternative use (e.g. to improve soil) will be an important dilemma to resolve.

Finally, especially considering the increasing range and production challenges of new advanced feedstocks, it is likely that both biological and thermochemical processes will be needed to satisfy demand.

Carbohydrates

- Typically food crops – sugar and starch
- Used for fermentation and distillation into ethanol

Lipids

- Oil-based crops such as sunflower, rapeseed and many more
- Used for chemical conversion into FAME
- Or for hydtrotreatment to convert into renewable diesel

Cellulosic feedstocks

- Indigestible or hard to process organic matter
- Lignin and Cellulose are the building blocks of a plant's structure
- Can be broken down into digestible carbohydrates or converted thermochemically (or a combination)

Advanced feedstocks

For more information:
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