Biofuels: NextChem innovative proposition to drive the future of transportation

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1. Context

> *It is time for the energy segments to mobilize themselves to limit or remove CO_2*
>
> P. Folgiero – CEO of Maire Tecnimont and NextChem

Discovery of biofuels traces back to 20th century, when Henry Ford designed his first Model T engine to run on ethanol. Although, as massive supply of fossil fuels became available, biofuels competitiveness decreased. Nonetheless, as regulations (mainly in EU and US) and environmental concerns regarding fossil fuels rise, an urgency to search for cleaner, renewable fuels emerges. Therefore, the search for solutions to blend or replace traditional fossil fuels with biomass-based fuels has begun. As emerged during the 50th World Economic Forum in Davos, maintaining a “business as usual” level of activity is no longer acceptable. The energy sector must take immediate steps to reduce carbon emissions and, in particular, the transportation segment needs to embrace higher levels of biomass-based fuels.

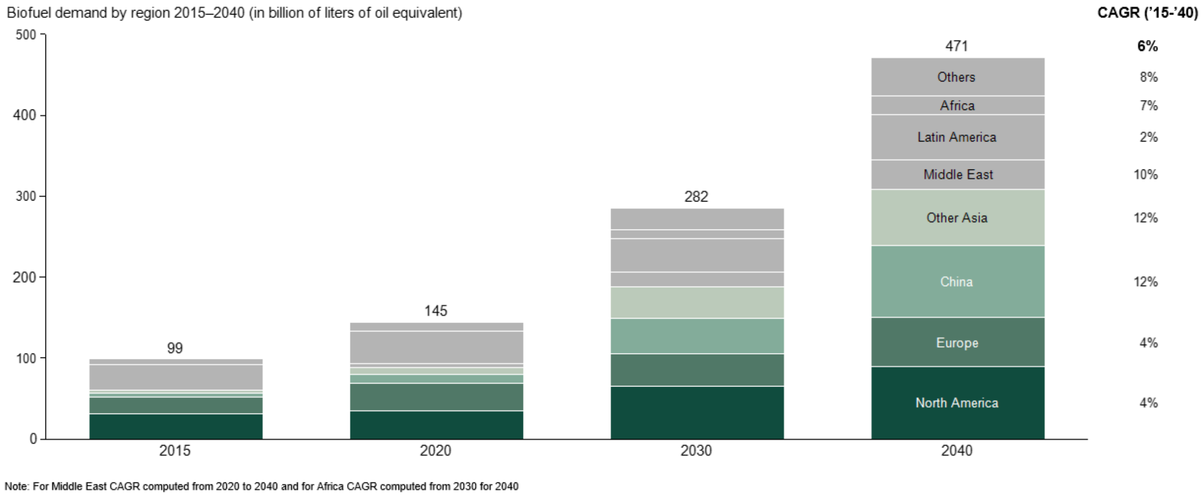
Regulatory schemes[1] – EU long-term trajectory is to move towards zero CO_2 emissions by 2050. To support this transition, the EU Parliament adopted the Renewable Energy Directive II (RED II) on December 2018: increasing blending requirement on fuel distributors and promoting advanced biofuels. Therefore, consumption must shift away from fossil and crop-based fuels and reach, by 2030: (1) 40% reduction in GHG; (2) 32% of renewables across sectors; (3) 14% of renewables in transport. In addition, defined restrictions are set to reach the 14% renewables target in transport: (A) biofuels produced from food and feed crops cannot exceed 7%; (B) biofuels produced from animal fats and used cooking oil cannot exceed 1,7% (limits can be adjusted according to country specific availability of feedstock), ensuring a competitive advantage to fuels that are still being commercialized and developed; (C) minimum of 1,7% for biofuels produced from agricultural residues, municipal solid waste.

The strong EU commitment to shift progressively towards renewables sources of fuels is aligned with other regulatory schemes around the world. In fact, similar mandates are available also in US, where the Environmental Protection Agency (EPA) set – through the Renewable Fuel Standard II Program – a specific annual volume requirement for renewable fuels. The same agency also published a defined regulatory framework – applicable to domestic and foreign producers and importers of renewable fuels used in US – to demonstrate that their biofuels meet the minimum GHG reduction standards based on a lifecycle assessment.

[1] Source: EU Commission, Environmental Protection Agency, Greenea

Given the above, as depicted by the graph below (Figure 1), EU and USA currently hold ~50% of the overall global market share for biofuel. Yet, Asian countries – and in particular China – are forecasted to significantly increase their rate of growth in the period between 2015 and 2040 with an estimated CAGR of 12%, eventually reaching ~30% of market share by 2040.

Figure 1: Global biofuel demand by region (2015 – 2040)



Source: IEA

Within the area of biofuels, a wide variety of fuel exist. All these may have different characteristics and functions according to the type of feedstock used.

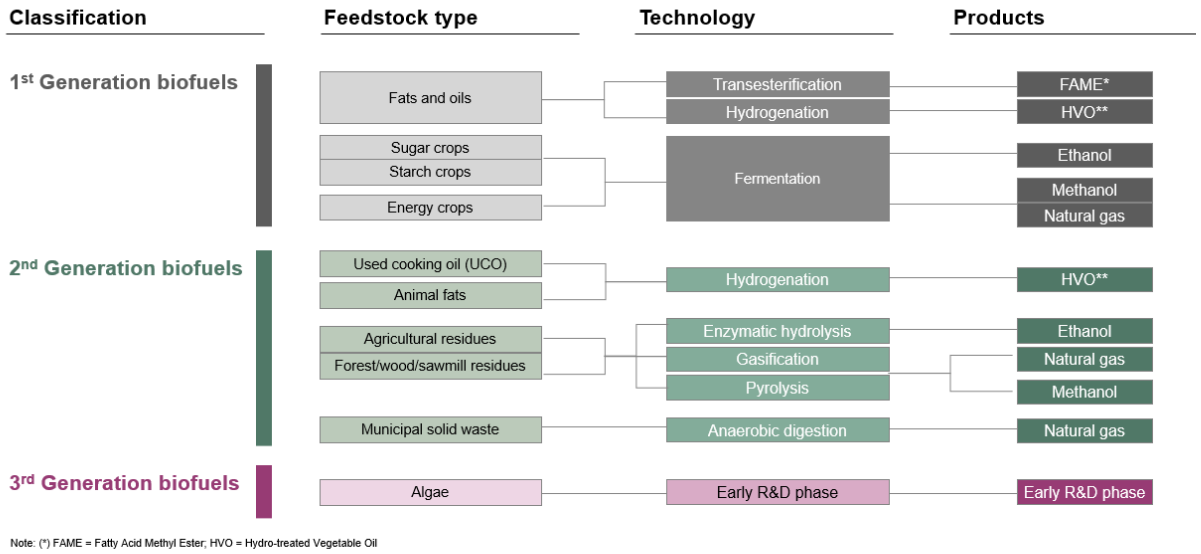
Use of biological components as feedstock

Biofuels are liquid and gaseous fuels derived from organic matter; common feedstock include sugarcane, corn, wheat, grass, used cooking oil, animal fats, municipal waste, algae, etc.

According to the type of feedstock, the International Energy Agency (IEA) recognized three main types of biofuels: conventional, advanced and novel advanced biofuels. The same are also alternatively classified – by the United Nations – in 1G, 2G and 3G biofuels:

- **Conventional (or 1G):** fuels produced from food crops, utilizing the starch, sugar and fat in them;
- **Advanced (or 2G):** fuels produced from non-food crop feedstock, which are capable of delivering significant lifecycle greenhouse gas emissions savings compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts;
- **Novel advanced (or 3G):** fuels produced from Algae, with higher yield and lower GHG emissions.

Figure 2: Main biofuels per types of generation: from feedstock to output products



Source: NextChem

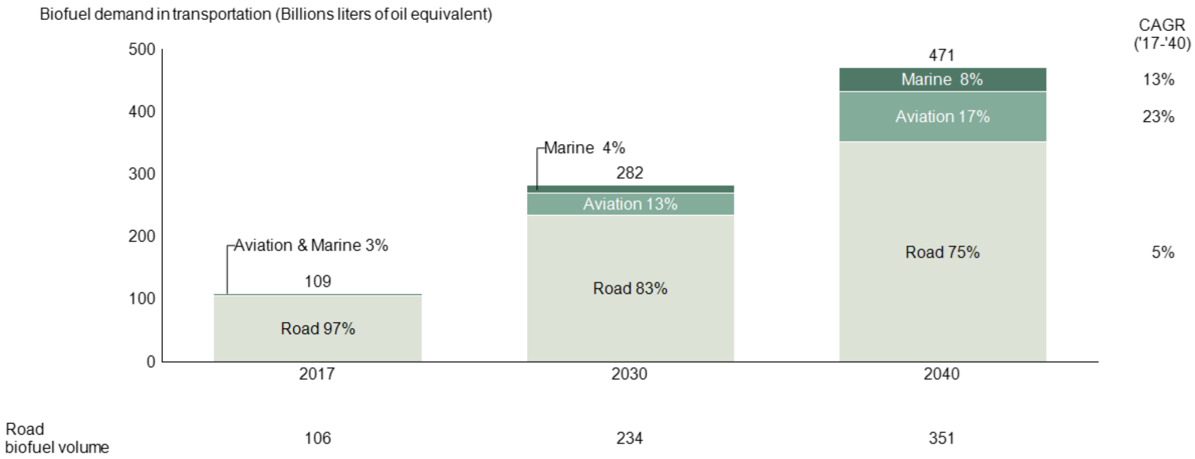
Demand – Biofuel is mainly used in transportation. Within transportation, road sector is the predominant user of such fuels, although aviation fuel is expected to have the fastest growth. Indeed, as depicted in Figure 3, global biofuel demand in road transportation is forecasted to increase steadily in 2017–2040, with a compound annual growth rate of ~5% - thus, reaching an overall volume of ~350B of liters of oil equivalent globally. Aviation use will increase – in the period from 2017 to 2040 – with a 23% CAGR (landing at an overall value of ~80B of liters of oil equivalent), driven by intense regulation. For instance, international agencies are setting the following objectives:

> *We are opening the door to a new Petrochemical Golden Era: it is the time for biofuels*
>
> P. Folgiero – CEO of Maire Tecnimont and NextChem

- **International Air Transport Association (IATA):** (A) improve average fuel efficiency in aviation by 1.5% per annum until 2020; (B) reduce net CO2 emissions from aviation by 50% relative to 2010 levels; (C) reach 1 billion passengers on flights fueled by sustainable aviation biofuels by 2025;
- **International Civil Aviation Organization (ICAO):** (A) introduce Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to realize IATA's carbon-neutral growth mission;
- **Advisory Council for Aviation Research in Europe (ACARE):** (A) reduce carbon per passenger kilometer by 50%, relative to 2000 levels;

- **EU Agency**: (A) biofuel Path Flight Initiative which calls for ~2 Mt of bio jet fuel to be used in aviation by 2020; (B) utilize 40% of sustainable low carbon fuels in aviation by 2050.

Figure 3: Biofuels demand in transportation (2017 – 2040)



Source: IEA

Comparing biodiesel and renewable diesel[2] **–** by comparing FAME and HVO, two of the main products represented in Figure 2, key differentiating elements emerge.

Produced from biomass, FAME is mainly used as a transportation fuel. The most common feedstock are refined vegetable oils (e.g. soybean oil) as they allow for simple and high-volume production, both in terms of feedstock sourcing and production processes. Generally, FAME production process consists on trans-esterification of triglycerides into methyl-esters, using alkali-catalysed reactions. On average, for a ~30M gallon facility, this mechanism requires an estimate CAPEX of 0,4-0,5 €/L.

The significant differences in terms of chemical structure between FAME and traditional diesel explains why this type of biofuel is used only as drop-in elements in diesel (usually with a ration between 5-20%). Therefore, performance issues typically restrict high blending of FAME with petroleum diesel. Using an excessive amount of FAME as diesel blending may in fact damage rubber components in older vehicles and cause filter blockage.

Moving to the HVO, this type of biofuel is produced via hydrotreatment of triglycerides and FFAs into long-chain hydrocarbons. Thus, the production requires significant amounts of hydrogen from an on-site facility or pipeline. Despite the more expensive production process

[2] Source: Bain analysis based on Energy Information Administration, Biomass for Energy and the Environment

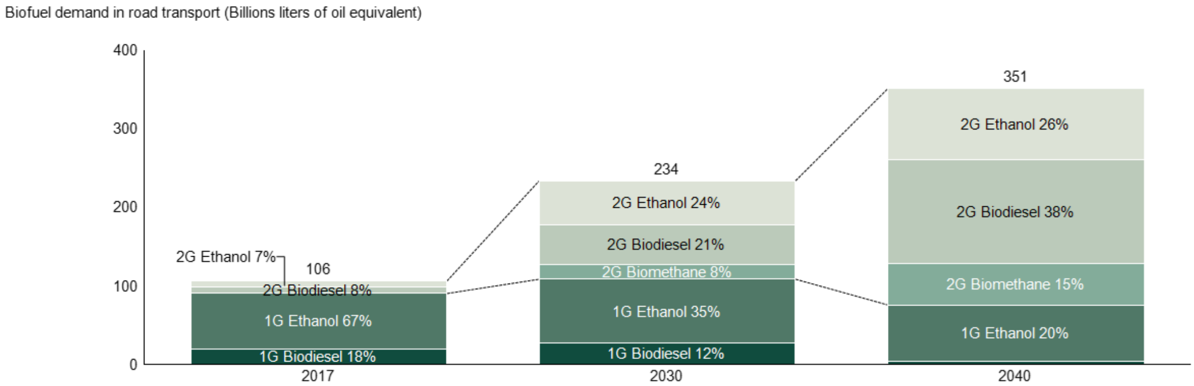
(vs. FAME), with a CAPEX of typically 1-1,2€/L (assuming a ~50M gallon facility), HVO shows some clear competitive advantages when compared to FAME fuels.

First, due to its better freezing temperature and storage characteristics, HVO is a direct substitute of petroleum diesel. HVO chemical structure similarity with diesel allows to sell this biofuel for the same price as diesel. Moreover, this translates to a flexible production process: (A) intrinsic input flexibility as all bio-based feedstock can be used as raw material without additional pre-treatment; (B) lower transportation costs considering that, given its chemical similarities with fossil diesel, it can travel in normal pipelines without interfering.

Finally, when looking at CO_2 reduction vs. fossil diesel, FAME and HVO present similar results. In fact, the two processes may lead to a GHG emissions reduction between 15-70%, according to the type of feedstock adopted.

In terms of biofuels evolution, HVO and more in general advanced biofuels (or 2nd generation biofuels) are likely to be the driving force of this evolution, as they mitigate sustainability risks associated with changing land use and competition over food production. Today most of these technologies are still highly capital intensive, hence new investments in these segments are required to reach full maturity, and finally drive down production costs, eventually getting close to FAME's cost levels.

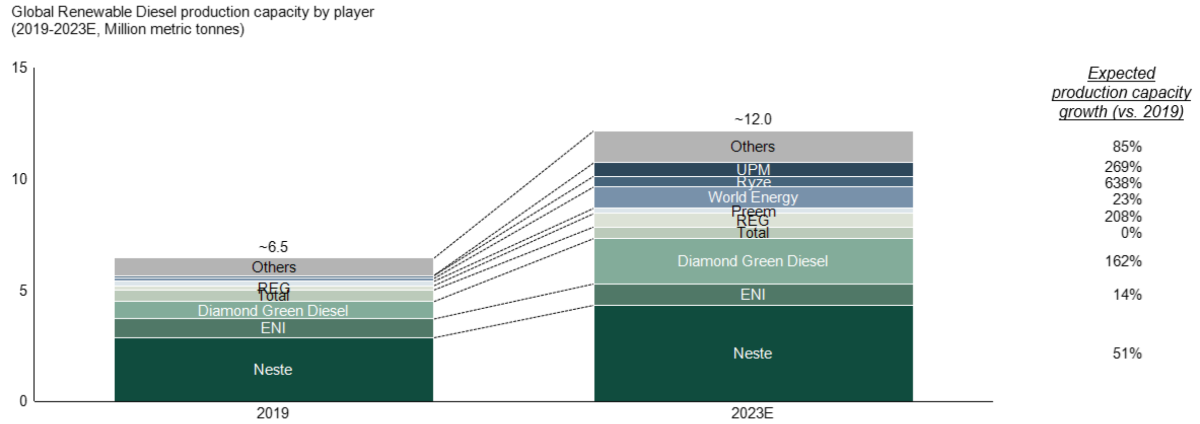
Figure 4: Biofuel demand evolution in road transport (2017 – 2040)



Source: IEA

Rise of HVO – Majorly driven by its technical characteristics and the incentives governments are offering for the production of bio-solutions, HVO is experiencing (and will continue to experience) significant progress in terms of producers' investments for the construction of new plants. If in 2019, the global production of HVO is estimated around ~6,5 million metric tons, in just four years – by 2023 – the overall capacity is expected to almost double – reaching ~12 million metric tons of fuel. In addition, as depicted by the graph below (Figure 5), the market is relatively consolidated with few players dominating the global picture.

Figure 5: Global HVO production capacity evolution (2019 – 2023)



Source: Bain & Company based on IHS Markit data

As depicted in Figure 5, despite the increasing governments' regulatory support in favour of biofuels alternatives, the competition in this segment of the market appears relatively concentrated. While the answer is clearly dependent on many country-specific reasons, one of the main causes lies on the early stage of development of this technology, which is extremely CAPEX intensive. Therefore, the current market is heavily reliant on regulatory incentives and tax schemes. Moreover, feedstock collection and in general the supply chain structure's fragmentation– as shown in Figure 6 – result in complex market dynamics.

Figure 6: Standard HVO supply chain

Feedstock originators	Collectors / Traders	Producers	Refiners	Distributors	Retailers	End users
Vegetable fats & oils	Small collectors	HVO producers	Own biofuel production	Jobbers	Travel centres	Fleets
Used Cooking Oil	Large collectors			Traders	Convenience stores	Personal cars
Animal fats	Traders		No biofuel production	Exclusive distributors	Cardlocks	Off-road users
				Others	Others	Others

Source: Bain & Company

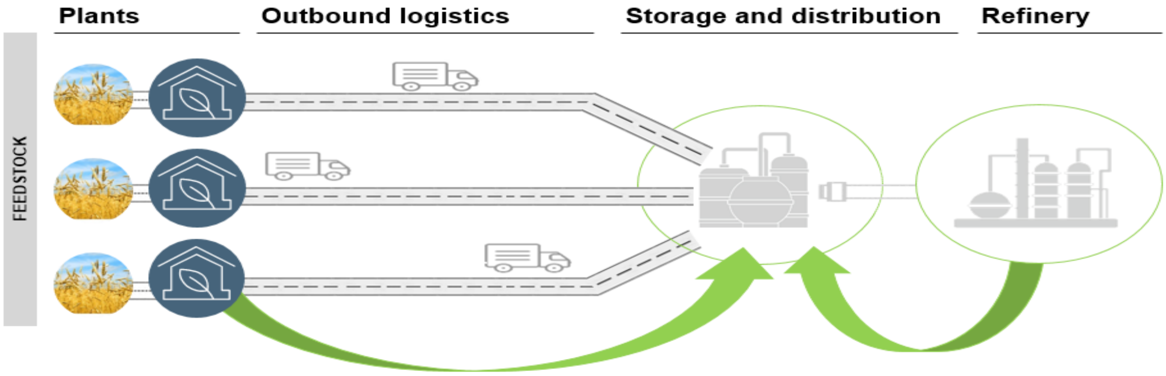
2. Business models to scale up

As anticipated, the biofuel industry has a complex supply chain. In particular, supply and logistics related to feedstock results in costly efforts from companies. Suffice to say that concerning UCO (used cooking oil) – a typical feedstock used for HVO – biofuels producers have to collect this oil from restaurants and food manufacturing facilities where concentration is highly fragmented. In most of the cases, HVO producers arrange a number of selected agreements with resellers who aggregate volumes from smaller collectors of feedstock through 3-5 years agreements. The agreements are particularly important since; despite UCO is a traded commodity with price indexes available, the market fragmentation and the significant difference found in the quality results in market inefficiencies.

As for UCO, similar issues may arise also for other common biofuels feedstock. In fact, while supply of other biofuel feedstock may not be as fragmented as UCO's, in most of the cases large quantity of bio-based feedstock are concentrated in specific geographical areas. This aspect brings us to discuss the second challenge of HVO, and more in general biofuels, which is the challenge to guarantee a constant flow of feedstock, in terms of both price and quantity. So how can companies secure feedstock supply while maintaining price competitiveness?

Nowadays, two distinct business models are emerging. In the first case biofuel producers' built-up various plants, also leveraging different technologies, locating them in separate areas with respect to other existing assets. This allows them to benefit from multiple pools of feedstock and at the same time gives them the flexibility to supply their own refineries as well as third parties' refineries. On the other hand, this may imply higher logistics costs equating to higher CAPEX and OPEX, linked to the number of different plants. For instance, Diamond Green Diesel has its largest plant located in Norco (Louisiana, US), area with one of the highest densities of multi-feedstock sources and animal fats.

Figure 7: Overview of a distributed business model



Source: NextChem

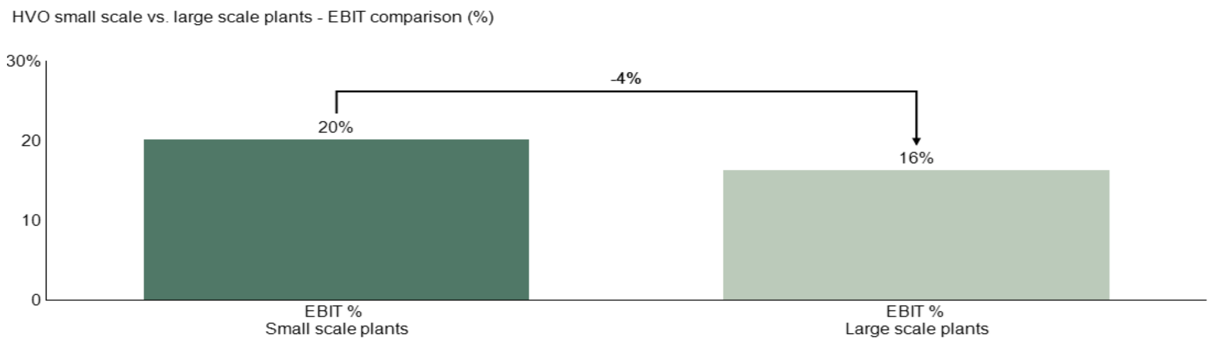
In the second case, instead, biofuels plants are integrated with existing assets and therefore have the potential to directly fuel existing refineries. In this case, producers would provide a higher valorisation to existing assets, eventually creating significant cost synergies and reductions in CAPEX. Yet, at the same time, these plants would suffer from a lower flexibility and they would be more subject to feedstock uncertainty linked to the specific location. Amongst large Oil & Gas producers, Phillips 66 has recently signed a collaboration agreement with REG to install a new renewable diesel plant adjacent to an existing Phillips refinery in US.

To solve the apparent trade-off between feedstock price stability and security of volumes, NextChem proposes an innovation to the distributed business model with the introduction of the game-changing concept of small-medium scale plants.

When comparing small and large scale HVO plants, different considerations and drawbacks can be outlined. When dealing with larger scale plants, two clear advantages emerge: (1) higher volumes produced; (2) higher efficiency at operational levels, including spreading of fixed costs and higher utilization rate. Oppositely, analysing the concept of small-scale plants, many more advantages can be depicted: (1) lower CAPEX to build operational plants; (2) higher flexibility in terms of feedstock, as smaller quantities are needed there is no need to secure high feedstock volumes; (3) lower logistics costs, associated with feedstock proximity and therefore low dependence on remote and far-away distributed feedstock fields; (4) possibility to integrate with other plants (e.g. refineries, ethanol plants etc.).

Definitely shifting the balance in favor of small-scale HVO plants, these plants have shown to yield a higher marginality compared to large-scale plants. Therefore, the lower CAPEX and the operational savings out-balance the higher efficiency rate of large-scale plants. (See Figure 8).

Figure 8: Standard EBIT (%) comparison between HVO small-scale and large-scale plants



Note: The small-scale plant has average size of ~50kta capacity and uses corn oil as 100% of feedstock; the large scale is referring to a plant facility with capacity of ~1.300kta, using 85% mix of waste & residue and 15% corn oil

Source: NextChem

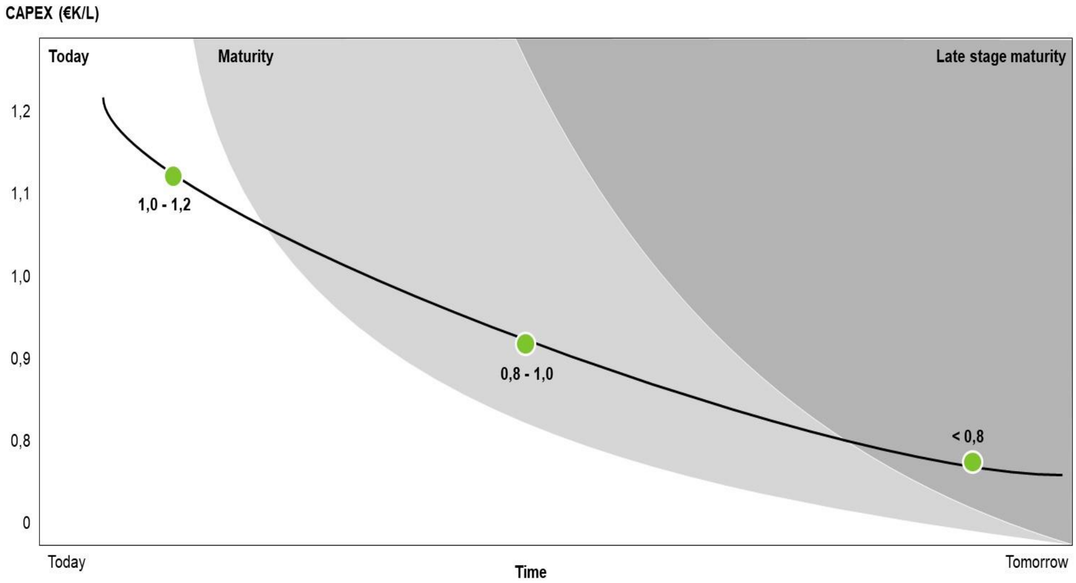
Case Study – Small-scale HVO plant: superior performances through modular and standardized applications

Renewable Diesel (also known as Hydro treated Vegetable Oil or HVO) and traditional Biodiesel (also known as Fatty Acid Methyl Ester or FAME) are often confused. Both can be made from vegetable oils and residual fats but they are produced differently: Biodiesel by trans-esterification and Renewable Diesel by hydro treating. While FAME presents limits of blending with fossil diesel, Renewable Diesel is a drop-in fuel that meets the petroleum fuel ASTM D975 and EN 590 standards. It overcomes blend limits and is currently used in existing diesel engines without any constraint, and with superior properties versus fossil and FAME.

In the Hydrogenated Vegetable Oil space, while main projects as of today focus on relative large scale plants (200-600KT per annum), NextChem has in its portfolio, in partnership with the American company Saola Energy, an innovative solution for small scale plants (20-40KT per annum). Such solution enables to tackle feedstock availability limitations while reducing logistics, transportation and operations complexity costs. Furthermore, small scale model allows to distribute the treatment of feedstock next to its origination, then connecting the HVO biofuel to storage tanks. Plants can also be easily integrated to bioethanol production units, to use the Distilled Corn Oil by product as feedstock. In the first industrial scale plant in Kansas (US), with a capacity of 35KT per annum, mainly using corn oil as feedstock and with an HVO production efficiency of 96%, NextChem is going to operate an innovative and proprietary pre-treatment and hydrotreatment technology that allows to treat a large variety of feedstock, including the most “difficult ones” (e.g. acid oils).

When looking at future development, NextChem’s aim is to standardize packages and equipment with a modular approach in order to bring down the CAPEX costs below 0,8€/l from the current 1,0-1,2€/l, and in parallel to ensure a fast time to market and a simple project execution.

Figure 9 – NextChem HVO technology cost curve, CAPEX over time



Source: NextChem

3. Partnerships and collaborations

Expanding into biomass-based fuels requires oil companies and industrials to adapt to different business dynamics and to deal with different supply chain than those of their core business. The wide array of potential feedstock and related management dynamics differ substantially in terms of regulations and incentives, of supplier landscape, pricing logics, and processing technology. The strategy required to succeed in such a setting relies heavily on the ability to extract value, adopting an integrated approach between intake and offtake, while leveraging the most fitting treatment technology.

> *Oil companies and biofuel producers need to step up cooperation to meet challenge of energy transition*
>
> P. Folgiero – CEO of Maire Tecnimont and NextChem

In such context, partnership and collaboration within the value chain will be critical. Indeed, the majority of players who have entered the market have done so by joining forces to share the risks and accelerate innovation (e.g. American refiner Valero and Darling Ingredients have entered a JV to build an 18,000-barrel-per-day renewable diesel refinery near the Valero St.

Charles Refinery in Norco, Louisiana, to process animal fats, used cooking oil and inedible corn oil into renewable diesel fuel).

NextChem is fully embraces the quest to accelerate energy transition and aims at identifying oil substitutes to produce chemical intermediates, fuels and plastics from renewable sources. Our technological background and leadership in the transformation of natural feedstock, makes us the ideal partner for the industrialization and commercialization of sustainable innovation.

Following the principle of low capital intensity, collaborations and scouting, we are able to bridge the gap between the idea born in the laboratory and the production on an industrial scale. We are industrializers of innovation and we are already partnering with major players in biofuels to develop technology fit for each of their purpose.

More information on NextChem can be found online: www.nextchem.com

Disclaimer

The above document and all its related analysis have been executed between January and February of 2020. Therefore, possible implications and consequences tied to the spread of COVID-19 are excluded.

As COVID-19 situation, as well as oil price shock, continues to evolve and companies (across industries) are temporary forced to shut down their activities – thus, creating frictions in the overall business environment – estimates might be re-considered.