ADVANCE FUEL

Conversion technologies of lignocellulosic biomass to advanced fuels

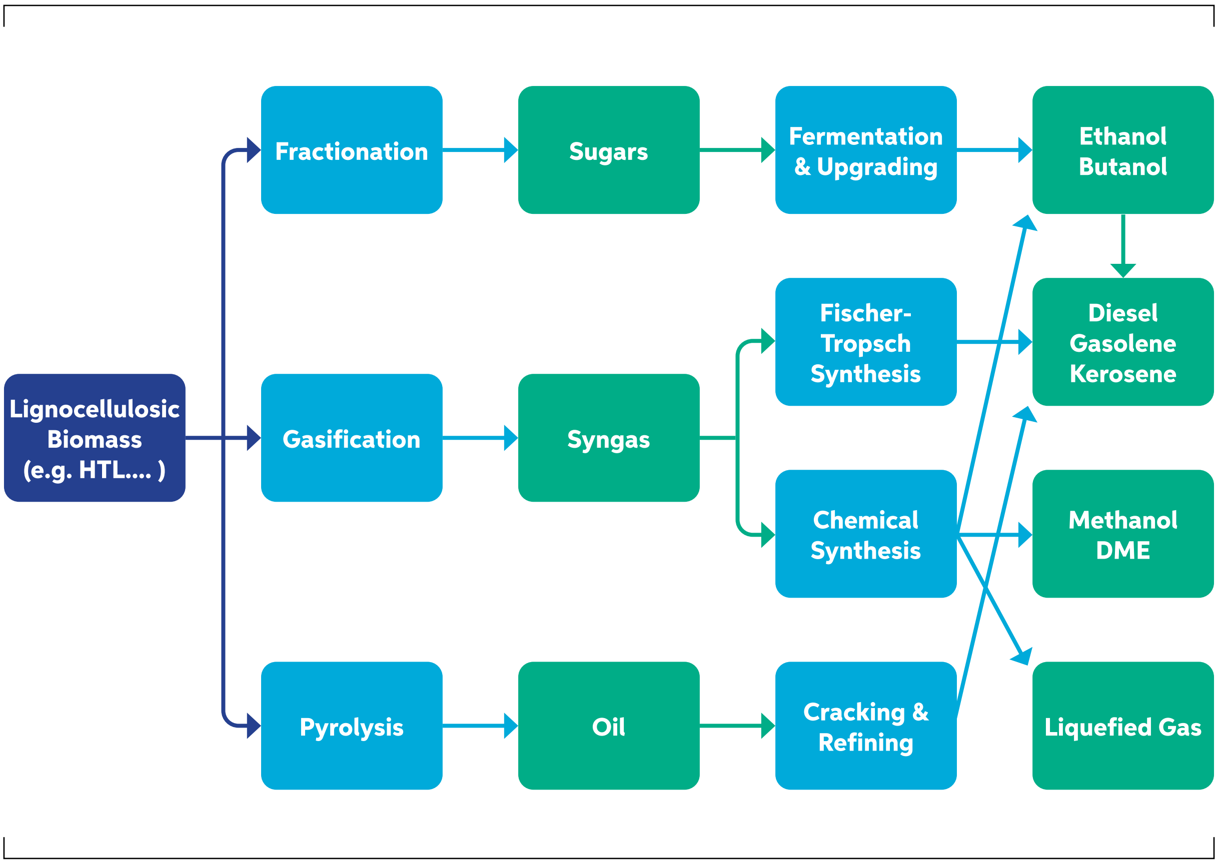
Context

Lignocellulosic biomass is a critical feedstock for advanced biofuels requiring different conversion technologies to upgrade the biomass to qualities for biofuels used in road, aviation and maritime transport. The conversion technologies for lignocellulosic biomass vary in terms of technology readiness levels (TRLs); in the scope of ADVANCEFUEL, conversion technologies ranging between TRLs 6-9 can be classified by the chemical pathway of the biomass conversion – either by thermochemical or biochemical pathways.

This factsheet provides an overview of the current status of lignocellulosic biomass conversion to advanced fuels with respect to TRLs, productions costs and opportunities for cost reduction that could support their successful market roll-out.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N.°764799

FIGURE 1. **CONVERSION PATHWAYS INVESTIGATED IN ADVANCEFUEL.**



Not exhaustive (HTL and hydrogenations, syngas fermentation are not included).

Conversion technologies state-of-the-art

Though TRLs generally vary from 6-9, higher TRLs include ethanol via fermentation and methane/methanol/DME via gasification, while jet fuels via ethanol are at the lower end. Lignocellulosic ethanol has reached commercial scale production (40-60 MW) on lower heating value (LHV) basis, while only a few small gasification plants for methane and methanol have reached demonstration scale (maximum 20-30 MW). Larger units for commercial scale (60-130 MW) are in planning phase, while various feasibility studies are available for large-scale production (up to 500 MW). Gasification plants producing FT-liquids (50-70 MW) are reportedly under construction in the United States, while studies for gasoline producing plants at larger scale (200-400 MW) are under investigation.

Lignocellulosic conversion technologies are greatly variegated in terms of their TRL and state of the art., with very few commercial scale plants.

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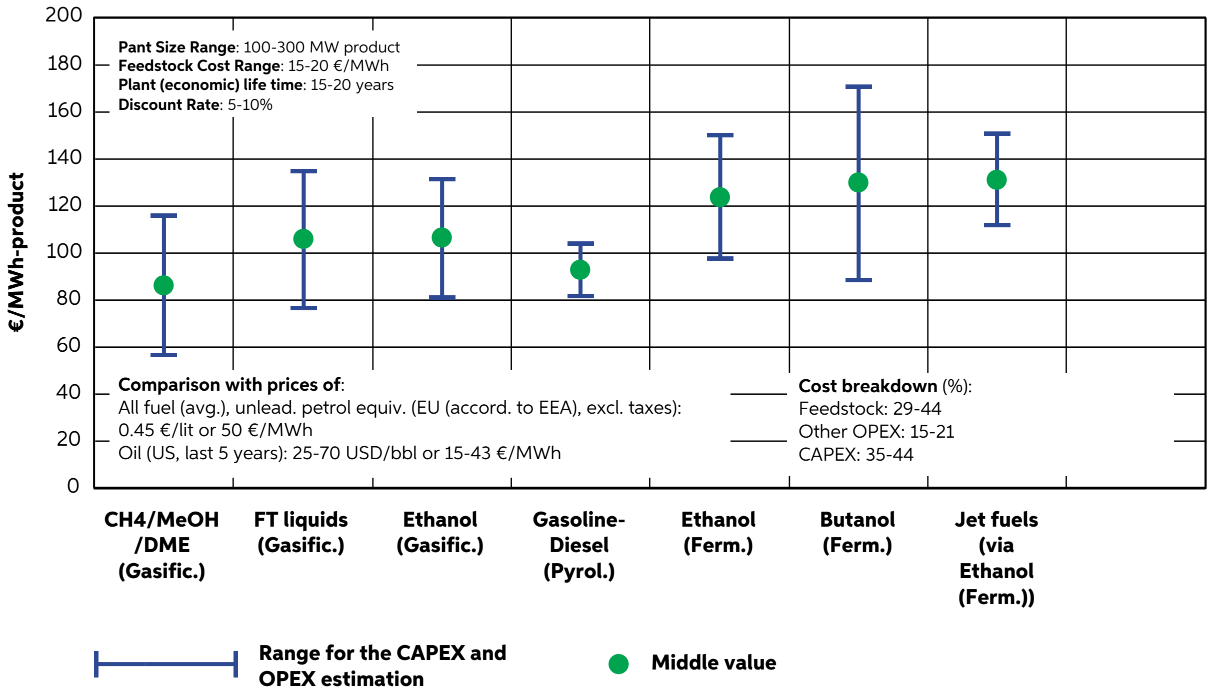
High production costs of advanced biofuels

Even under the most favourable cost calculations – large industrial scales, high feedstock efficiency, lower discount rates – comparing the production costs of technologies for advanced biofuels from lignocellulosic biomass with the price of conventional fossil fuels shows a significant gap of at least 20-40 €/MWh-product in favour of fossil fuels. At an initial phase, more competitive pricing can be achieved for advanced fuels through subsidies, but in the long-term the cost of using fossil fuels must be higher than that of biofuels.

FIGURE 2. **CURRENT STATUS (2020) OF PRODUCTION COSTS (€/MWH-PRODUCT) OF ADVANCED BIOFUELS FROM LIGNOCELLULOSIC BIOMASS.**



The ranges are indicative of studies providing cost information and the uncertainty of the corresponding cost calculations. Data has been adjusted to similar cost calculation parameters (i.e., plant size, feedstock cost, project lifetime, and discount rates).[1]

Additionally, high feedstock costs make up a large share of advanced fuel production costs, having important implications on policy measures. Increased use of biomass in other sectors may drive up feedstock prices, supporting the argument for higher costs on fossil fuels to encourage that biofuels are sourced in sectors and activities where substitution is currently difficult or costly.

To limit the high production costs, it should be secured that commercially available process technologies for the different processing steps – including product upgrading – require units of a sufficiently large size; however, high capital cost for the required large-scale production implies high financial risk.

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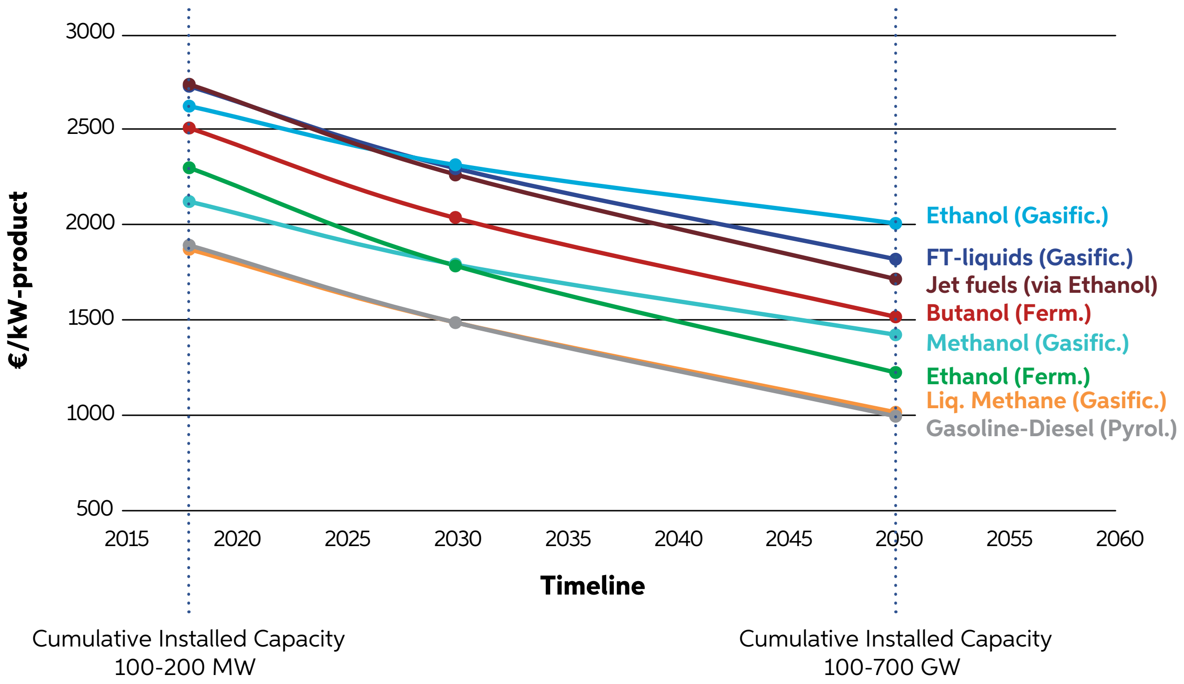
Scope for cost reduction

While large industrial scales are required to lower costs and to ensure high full-load hours, supply chain issues of lignocellulosic biomass can limit the capacity of the advanced biofuel plants. ADVANCEFUEL has assumed capacities of 100-200 MW for future advanced biofuel plants. Even though limited technical learning can be expected for equipment cost, cost reductions can be found in assembling plants by learning by doing approaches.

Applying learning theory for capital investment (CAPEX) reduction is based on parameters related to the cumulative annual growth rate of the corresponding technologies and learning rates of the technology components and their assembly in production lines. For marginally higher cumulative annual growth rates of advanced biofuels compared to the current market trends of the corresponding fossil fuels, CAPEX reductions of 10-25% can be expected in a future assuming only a handful of plants installed. If higher cumulative installed capacities are reached in 2050 to meet the goal of 20-25% of transport fuel consumption covered by advanced biofuels, CAPEX reduction up to 40-50% can be expected for the new plants that will be built.

FIGURE 3. **SCOPE OF CAPEX REDUCTION (2020-2050) OF ADVANCED BIOFUELS FROM LIGNOCELLULOSIC BIOMASS FOR A SCENARIO OF CAPACITY ANNUAL GROWTH RATE MEETING THE GOAL OF 20-25% TRANSPORTATION FUELS CONSUMPTION TO BE COVERED BY ADVANCED BIOFUELS IN 2050.**



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Integration into existing infrastructure

Various studies propose production cost reductions by integrating advanced biofuel plants in existing infrastructure. CAPEX reduction of integrated plants compared to stand-alone plants include:

- **15-40% reduction** by co-processing biogenic feedstock (bio-oil, FT-waxes) in crude oil refineries.
- **Up to 50% reduction** by co-location of 2nd generation bioethanol plant with infrastructure of 1st generation plants.
- **Up to 50% reduction** by integrating boilers (district heating, pulp mills) into gasification systems, increasing the existing boilers' performance by over 2½ times assuming full time operation of the advanced biofuel plant.

Oil and syngas platforms provide opportunities of processing biomass or biomass-derived intermediates by using existing facilities, such as oil cracking, hydrotreating, gasification, and chemical synthesis (FIGURE 4). In a future system, the intermediates can be produced within refinery sites or in connection to existing power or combined heat and power plants. The resulting products could include gasoline, diesel, olefins, alcohols, acids, waxes, and many other commodity chemicals derivable from syngas.

Gasification routes concerning the integration of biomass gasification with FT synthesis Biomass-To-Liquids (BTL) technology in oil refineries by heat integration and potential FT syncrude co-processing are other options of utilising existing fossil-based infrastructures. According to the reported ranges of 2-10% of blending bio-oil in FCC units (10% refers to the case of HDO bio-oil) an estimation of the potential HDO bio-oil could be done. The potential used HDO bio-oil would be approximately 10 Mm^3/yr HDO to be blended in the FCC units for the whole FCC capacity in Europe (approximately150 Mm^3/year).[2] This corresponds to approximately 6,400 MW bio-oil production (64 plants in Europe of 100 MW each) and would require 10,000-11,000 MW of lignocellulosic biomass (e.g., woody residues) to be converted in this bio-oil.

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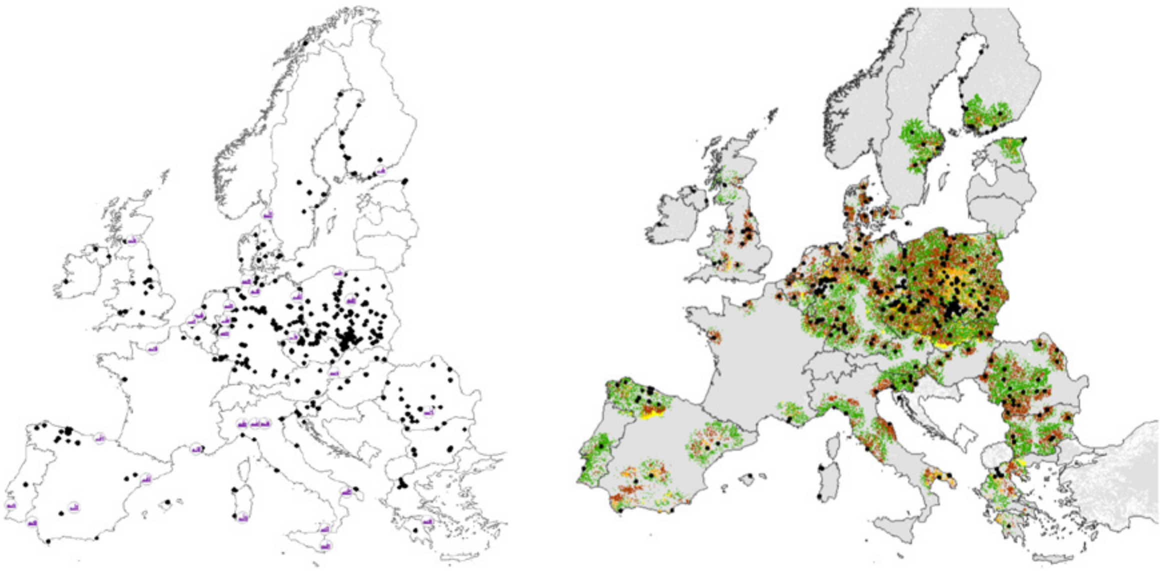
FIGURE 4. **FIGURE 4: INTEGRATION OF BIOMASS INTO FOSSIL-BASED INFRASTRUCTURES.**



Black dots indicate existing coal power plants suitable for the construction of bio-oil units and/or biomass co-firing. **Purple dots** indicate oil refineries suitable for bio-based feedstock (co-processing of bio-oil). **Coloured areas** correspond to feedstock used to cover the demand (200 km transport limitation).[3]

Using existing infrastructure keeps transaction costs low. Wherever it is difficult to build new plants due to various constraints, new biomass-conversion plants could be built in existing industrialised areas to benefit from process know-how in energy plants and refineries.

Conclusions

There is a significant gap between production costs of advanced biofuels and prices of fossil fuels. It should not be expected that in short- to mid-term (e.g., by 2030) this gap can be fully bridged by technical improvements.

In long-term, a significant role in improving technical efficiencies and operating costs can be the advanced utilisation (e.g., by catalytic hydrogenation) of the lignin fraction from biochemical pathways towards fuels and chemicals, as well as the efficient utilisation of biogenic CO_2 sources via power-to-fuels approaches.

After installations of hundreds to thousands of plants and efficient use of the existing biomass handling and fuel production infrastructure, investment reductions of 40% to 50%. Operating costs can be further reduced by process integration at large-scale, however they may also be negatively affected by the increasing demand of biomass.

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For more information see the following ADVANCEFUEL reports

- D3.2 Definition of biomass reference technologies with respect to TRL and performance indicators
- D3.5 First data on efficient, low-risk ramp-up of liquid biomass conversion technologies - from short time to long term
- D3.6 Efficient, low-risk ramp-up of liquid biomass conversion technologies - from short time to long term

References

1 D3.2 Definition of biomass reference technologies with respect to TRL and performance indicators

2 Barthe, et al., 2015 – Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil and Gas [Report]. - Seville, Spain : European Commission.

3 Cintas et al., 2018 – Geospatial supply–demand modeling of biomass residues for co-firing in European coal power plants, Bioenergy, 10, 786-803.

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