# How to advance cellulosic biofuels

## Assessment of costs, investment options and policy support

- Final Version–

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## Assessment of costs, investment options and required policy support

- Final Version –

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In December 2015, world leaders agreed a new deal for tackling the risks of climate change. Countries will now need to develop strategies for meeting their commitments under the Paris Agreement, largely via efforts to limit deforestation and to reduce the carbon intensity of their economies. In Europe, these climate protection strategies will be developed via the EU's 2030 climate and energy framework, with a view to ensuring an integrated single market for emissions reduction technologies.

Existing EU energy policy for 2020 foresees an important role for bioenergy as a means of reducing carbon emissions from heating, power and transport, and yet there are concerns that this has led to a number of negative consequences related to the intensification of resource-use. If bioenergy is to continue to play a role in EU energy strategies for 2030, it seems wise to learn from the past to ensure that this is done in a manner that is consistent with the EU's environmental goals, including the 2 degrees objective.

With this in mind, the European Climate Foundation has convened the *BioFrontiers* platform, bringing together stakeholders from industry and civil society to explore the conditions and boundaries under which supply-chains for advanced biofuels for transport might be developed in a sustainable manner. This builds on work developed in the ECF's *Wasted* platform in 2013-2014, which focused on waste- and residue-based feedstocks for advanced biofuels. This time around, there is an additional focus on considering land-using feedstocks and novel fuel technologies.

As the name *BioFrontiers* suggests, this discussion enters new territory and is faced with numerous gaps in knowledge. To facilitate a transparent and constructive debate between industry and civil society, the ECF has commissioned a number of studies to help fill such knowledge gaps. This is one such study. It does not represent the views of the members of the *BioFrontiers* platform, merely an input to their discussions. If this research also helps inform the wider debate on the sustainability of bioenergy, that is a bonus. I would like to thank Ecofys for using the resources provided by the ECF to improve our understanding of these important issues.

Pete Harrison
Programme Director, Transport
European Climate Foundation

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A study into the cost profile and investment situation of advanced biofuels requires good data and the best data source are of course companies active in the market such as biofuel producers and investors. Ecofys and Passmore Group are grateful for the information provided by a range of companies in the EU and US. We are particularly grateful for those companies who provided us with commercially sensitive data on production costs of advanced biofuel plants and their investment structure. This information greatly increased the robustness of our estimation of production costs.

We also would like to thank the Chris Malins of the International Council for Clean Transportation (ICCT) and Pete Harrison of the European Climate Foundation (ECF) for their critical comments and suggestions.

# Abbreviations

| | |
|---|---|
| BESTF2 | BioEnergy Sustaining the Future 2, *EU support scheme for demonstration plants* |
| $CO_2$ | Carbon dioxide |
| EC | European Commission |
| EIBI | European Industrial Bioenergy Initiative, *EU initiative to support FOAK plants* |
| EPA | (US) Environmental Protection Agency |
| EU | European Union |
| FOAK | First-Of-A-Kind, *first generation commercial scale plant* |
| FQD | (EU) Fuel Quality Directive |
| GHG | Greenhouse Gas |
| HPO | Hydrogenated Pyrolysis Oil |
| ILUC | Indirect Land Use Change |
| IP | Intellectual Property |
| k | Thousand [units] |
| M | Million [units] |
| NER | New Entrants Reserve, *reserve of free allowances for new entrants to the EU ETS* |
| NOAK | Nth-Of-A-Kind, next generation commercial scale plant |
| RED | (EU) Renewable Energy Directive |
| RD&D | Research, Development and Demonstration |
| RFS | (US) Renewable Fuel Standard |
| ROI | Return On Investment |
| TME | Tallow Methyl Ester |
| UCOME | Used Cooking Oil Methyl Ester |
| US | United States |
| VAT | Value Added Tax |
| WTW | Well To Wheel |

# Executive summary

The use of advanced biofuels, meaning here those produced from agricultural or forest residues or energy crops[1], in transport is generally viewed as a sustainable manner in which to mitigate the growing climate impact of the transport sector. However, the share of advanced biofuels in the total supply of biofuels in the EU is low. Less than 1% of the total EU fuel mix consists of advanced biofuels. This limited relevance of advanced biofuels in the current marketplace does not reflect the importance that EU policy makers attach to these biofuels, which often have a better sustainability and greenhouse gas saving performance than conventional biofuels. Much more is possible, especially when looking at the total availability of biomass residues in the EU.

Why has the uptake of advanced biofuels been so slow? Generally, it comes down to an assessment of risk, and the certainty of receiving returns on investor's capital deployed. Advanced biofuels projects still carry many risks. Capital costs are high, some technologies are not widely tested at commercial scale and little certainty exists that produced fuels can be sold to the market at a sufficiently high price, as the regulatory climate to ensure long-term offtake has been lacking. Clearly, more investments are required. But that investment can only come with market certainty and an assurance that risks can be reduced, eliminated or properly allocated. How can the uptake of advanced biofuels be accelerated more effectively? To address this question, we describe the barriers for increased deployment of advanced biofuels, focusing on the main barrier: high production costs. Subsequently we assess which types of investors would be willing to finance investments in advanced biofuels and we assess which policies could eliminate barriers and attract investment.

**Production costs**

We estimated production costs for three biofuel pathways: Cellulosic ethanol produced from agricultural residues, Fischer-Tropsch renewable diesel produced from woody biomass and Hydrotreated Pyrolysis Oil produced from woody biomass. Estimated costs for cellulosic ethanol and Fischer-Tropsch renewable diesel produced in next generation commercial facilities (nth-of-a-kind, NOAK) are modelled using assumptions (see Appendix) and data obtained from various sources. A cost estimate for Hydrotreated pyrolysis oil produced in a NOAK installation is based on a study by Pacific Northwest National Laboratory (PNNL) published in march 2015.

We estimate that production costs for a next generation commercial scale cellulosic ethanol can be as low as 750 EUR/tonne, whereas costs for a current first generation plant (FOAK) stand at around 1,000 EUR/tonne. These figures do not include margins for biofuel producers. Total average revenues are estimated to be 1,004 EUR/tonne including a limited double counting premium for the biofuel producer. The double counting premium is the difference between the price of conventional ethanol

[1] More specifically we only consider material high in cellulose, lignocellulose and lignin components. This study does not consider biofuels produced from used cooking oil or animal fats or algae.

and petrol, we assume that this premium largely ends up with the fuel supplier rather than with the biofuel producer. When comparing costs with revenues it becomes clear that cellulosic ethanol is currently not economically viable without additional policy incentives.

Pyrolysis oil can be used as a transport fuel when hydrotreated (resulting in hydrotreated pyrolysis oil or HPO) or when directly used in the refinery fuel production. Both routes are not yet implemented at commercial scale, making it difficult to accurately estimate total production costs. PNNL estimates HPO production costs to stand at 1,647 EUR/tonne. While this means that today it is difficult to produce HPO at commercial scale, the PNNL study shows that significant cost reductions have been achieved in recent years and if this trend continues, costs will have come down to 1,100 EUR/tonne in 2017 and lower costs in subsequent years. This means that HPO might start to play a role at commercial scale after 2020. As with HPO, Fischer-Tropsch renewable diesel is thought to be relatively expensive, with an estimated production cost for NOAK plant of 1,315 EUR/tonne, which is double the market price of fossil diesel. Also for this pathway cost reductions are needed to make the technology attractive for investors. We do note that only a few reliable cost data sources for Fischer-Tropsch renewable diesel are available, meaning that significant uncertainties remain for the results for this pathway. At these cost levels, the carbon abatement cost of advanced biofuels vary strongly from 164 EUR/tonne $CO_2$ for cellulosic ethanol to 209 EUR/tonne $CO_2$ for FT biodiesel and 308 EUR/tonne $CO_2$ for HPO.

Based on our cost estimates it can be concluded firstly that of the three pathways cellulosic ethanol seems most attractive for investors and secondly that additional policy incentives are required to grow the market for advanced biofuels beyond the existing EU ‘double counting’ incentive.

**Investors (not) willing to invest**

Currently, advanced biofuel projects both in the EU and US have been mostly funded by companies themselves (Self-financing). This makes sense in a market with large regulatory and offtake risks, but in order to grow a thriving advanced biofuel industry at some point external investors will be needed to bring in more capital. In this study, eleven types of investors were identified that could play a role in funding advanced biofuel projects. In summary, of the eleven financing options reviewed, only **Self-financing** is identified as presenting a likely short term investment source for advanced biofuels. Self-financing means that large companies are prepared to invest their own capital not just in innovation at the R&D stage, but also in first-of-a-kind (FOAK) commercial projects. In many cases these companies are willing to take below market returns on a first of a kind project hoping that any project losses will be recovered by selling technology licenses to project developers.

Three external funding options, **Large Corporate Strategics[2], Investment Banks and Initial Public Offering[3],** are identified as possible investment sources under the right, and extremely optimal, conditions. Of these, Large Corporate Strategics seem the most likely if they can be

[2] Large companies with large balance sheets

[3] IPO represents a company’s first foray into the public markets to raise capital through the sale of shares of stock. IPOs are commonly issued by small to medium sized companies seeking money to expand their business. After the IPO, shares trade freely in the open market.

persuaded that an investment in advanced biofuels is in their long term best interest, and that such an investment will eventually have a material impact on their business. It could be interesting to combine several financing options, so to reduce the risks for individual parties, e.g. a combination of strategic investors, industrial parties, venture capitalists, pension funds and government money. Of course it would be challenging and time consuming to assemble all pieces. Such a combination ("capital stack") could finance projects provided all the deals can come to a close at or near the same time. In all cases, whether Strategics, or some syndicated group that an Investment Bank is able to assemble, all investors are unlikely to proceed if there is a hint of government policy instability. Given the cost of FOAK advanced biofuels facilities, any perceived threat of stranded assets will discourage investors. Essentially, certainty is the mother of investment, both in terms of markets and government policies.

The remaining seven options are not considered relevant for investments in advanced biofuel plants. The reasons for this vary, but typically come down to the large size of the capital investment required, a lack of appetite for technology and therefore project risk, and a fear of future change of law. Also, since advanced biofuels projects and their sponsors do not have a proven business track record and typically lack a strong balance sheet, proposed projects are not considered "investment grade" (have sufficiently low risks to investors) by traditional providers of debt. In other words, the proposed project investment does not meet the minimum acceptable rate of return for investors.

A general observation on financing first of kind commercial plants is that it is more of an art than a science, no fixed rules apply. Investment bankers, for example, will look for creative ways to put together the necessary capital to get a project built. People or entities that lend money want to be certain they are making a wise investment decision. Some lenders are prepared to take greater risks than others (have a higher "risk tolerance"), in which case their cost of capital may be lower than a lender who is highly risk averse and wants a high return for any risk (real or perceived) that the borrower is taking. So what works in one instance for a project capital raise may not work next time.

**Combination of policy measures to effectively mitigate investment risks**

In our study we assess how four policy measures could stimulate investments in advanced biofuel facilities: a specific mandate for advanced biofuels, a carbon intensity reduction target, a fiscal incentive (tax exemption) and investment support. For each of these measures their impact in reducing the offtake risk, regulatory risk, financing risk and feedstock risk are assessed. The table below summarises the extent to which the assessment policy incentives reduce risks for investors.

**Table - Impact of assessed measures in reducing investors' risks**

| Criteria | Mandate | Carbon saving target | Fiscal support | Investment support |
|---|---|---|---|---|
| Reduction of offtake risk | | | | |
| Reduction of regulatory risk | | | | |
| Reduction of financing risk | | | | |
| Reduction of feedstock risk | | | | |

**Green: risk can be reduced, yellow: risk can be partly reduced or unclear whether risk will occur, red: unlikely that risk can be reduced**

Feedstock risk will often not occur. In situation where it occurs, when a plant using agricultural residues in an area where the material is already widely used by other sectors. The most important risks to be mitigated from the perspective of investors are the offtake and regulatory risks. Measures can reduce the offtake risk either by enabling advanced biofuels to compete with conventional biofuels in the same market or by fencing off a market for advanced biofuels, by measures that decrease advanced biofuel production costs or by measures that increase revenues. A specific, high enough mandate for advanced biofuels, a specific high enough carbon saving target and a sufficiently high level of fiscal support can all reduce the offtake risk whereas from the perspective of an investor only investment support offers certainty from a regulatory perspective. This makes investment support an interesting accompanying measure to one of the other three.

The degree to which regulatory risk will materialise depends on the level of public support for advanced biofuels, if active support is widespread than either a mandate, carbon target or fiscal support (tax exemption) can reduce the offtake risk in a satisfactory manner. However, probably a specific mandate and specific carbon saving target offer more certainty than a fiscal measure because the latter is paid for from the government budget which makes it a potential target for savings in times of austerity, whereas the first two are paid for by consumers at the pump. Some increased regulatory certainty can be achieved by tendering fiscal support, which essentially prevents the measure to become an open ended bill for the treasury. Fiscal support can also play a helpful role not as stand-alone but as a supporting measure in the early commercialisation of advanced biofuels, to offer limited support for a fixed number of years in an advanced biofuel market that is primarily driven by a specific mandate or carbon target.

Either a specific mandate, a carbon target or fiscal support can deliver an increased deployment of advanced biofuels, ideally accompanied by a form of investment support to reduce high capital costs for first and second of a kind investments. Whether such a combination of policy measures or 'policy stack' can really mitigate risks depends on how measures are designed. A mandate, carbon target or fiscal support should be fixed for at least eight to ten years to allow investors to return their investment. Ideally, this period would be longer to enable investors a longer period to return their investment, but regulatory certainty for longer than ten years is probably not very realistic. Mandates should have a high enough buy-out price, should be specific for advanced biofuels and should be embedded in the right storyline in order to receive sufficient levels of societal support. A carbon saving target must allocate a specific part of the target for advanced biofuels in order to effectively drive investments in advanced biofuels. This means that dedicated, longer term policy measures will be required to really advance the market for advanced biofuels in Europe.

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# Introduction

Biofuels are supported by the European Union, primarily with the aim of reducing climate change emissions. In recent years concerns have increased over the greenhouse gas saving performance of biofuels, in particular due to Indirect Land Use Change effects. This led to an increased focus on advanced biofuels produced from biomass residues such as straw or forestry residues or from sustainably produced energy crops that have an overall better greenhouse gas saving potential and no or a low land use impact. To date, however, advanced biofuels[4] so far play only a minor role in the EU since they are currently expensive to produce compared to conventional biofuels.

Whereas conventional biofuels can be produced using well established technologies with low to moderate capital but relatively high feedstock costs, advanced biofuels produced from cellulosic material have low feedstock costs, but the more complex technology leads to higher capital costs (Capex). Furthermore, while the cellulosic feedstock is cheaper than for conventional biofuels, the other operational and maintenance costs are somewhat higher (e.g. enzymes, catalysts). Still, the total operational costs (Opex, including feedstock costs) for advanced biofuels should be lower compared to conventional biofuels in most cases. While a conventional bioethanol plant may have Capex of 40% and Opex of 60%, this split may be the other way around for cellulosic advanced biofuels. For biodiesel, by comparison, Capex may be 15% and Opex 85%, with Opex dominated by feedstock costs.

The high capital cost level is currently a barrier to investments in advanced biofuels. This means that advanced biofuel deployment will depend heavily on government policy incentives. Such incentives can continue to play a valuable role in stimulating further research and development (R&D) and in the development of demonstration facilities, but most importantly for the commercialisation of these technologies clear policy incentives can stimulate investment in first-of-a-kind commercial production facilities and provide confidence of offtake, meaning that there will be a market for the product. Production facilities are constructed in regions with a beneficial policy framework and a reliable supply of low-cost feedstock. Today, most cellulosic biofuel production takes place in the US, a result of specific financial support and mandates for cellulosic ethanol. Production capacity has also been constructed in Brazil and the first plant in the EU is located in Italy, an EU Member State with a specific blending mandate for advanced biofuels, and also Finland has also seen investment due to a favourable policy framework and feedstock supply.

The successful commercialisation of advanced biofuel projects requires capital. Why has this been so challenging? Why has the uptake of advanced biofuels been so slow? As this report will show, it comes down to an assessment of risk and the certainty of market based returns on capital invested. Advanced biofuels projects are still perceived to have many risks. Capital costs are high and a stable

[4] Meaning here those produced from cellulose material such as agricultural and forestry residues or energy crops

regulatory climate has been lacking. Investments can only be attracted if risks can be reduced, eliminated and/or properly allocated.

In this report, Ecofys and Passmore Group will analyse the cost profile and investment situation of advanced biofuels and based on this, will provide recommendations for the most effective policy measures to stimulate investments and increased production of these fuels.

We will first assess in Chapter 1 the main barriers for advanced biofuels. Chapter 2 analyses in more detail the main barrier: high production costs: How large is the cost difference with conventional biofuels and what factors have the largest impact on costs? Subsequently, Chapter 3 assesses the investment climate: which types of investors would be suitable and willing to invest in advanced biofuels and under what conditions? Finally, Chapter 4 analyses which policy options are most suited to eliminate these barriers and which will ensure a successful increased deployment of advanced biofuels.

# 1 Barriers for advanced biofuel deployment

The challenge for investors and policy makers is how advanced biofuels can become a viable alternative for conventional biofuels and fossil fuels, available in large quantities at acceptable costs. Significant barriers exist that hamper a large-scale deployment of advanced biofuels. These barriers can be technology related, feedstock related, financial and political. A recent study by ICCT on investment risks in advanced biofuels[5] concluded that "the most significant barriers to the commercial deployment of cellulosic biofuels are not technological but economic". Without a significant reduction in Capex or sufficient levels of policy support, advanced biofuels may well remain a fuel for the future instead of having a meaningful impact today. Barriers for advanced biofuels constitute risks for investors. The main barriers or investor risks are outlined in the box below.

**Box 1 - Main barriers for investments in advanced biofuels in the EU**

***High CAPEX.*** Capital costs of advanced conversion technologies are typically much higher than for conventional biofuels and cost reductions are crucial. One way to achieve a significant cost-reduction per volume of product is to increase the scale of individual plants, but while this may reduce costs per unit of fuel, it increases overall CAPEX. According to a recent review of US advanced biofuel markets, capital availability remains the greatest challenge to the commercialisation of advanced biofuel projects in the US where public funding continues to play a crucial role in industry development. Investors typically require a long-term feedstock-supply and off take agreements which can be difficult to achieve.

***Lack of adequate incentives*.** The main regulatory inventive for the development of cellulosic biofuels in Europe has been the double counting provision (Article 21(2) of the EU RED directive), combined with the value under the EU Fuel Quality Directive of the carbon savings delivered. These incentives do not provide enough value to make new cellulosic technologies with high perceived risks competitive with well-demonstrated low-CAPEX technologies to produce biofuel from wastes, and to date only one of these two measures has ever been active in any given Member State – the two incentives are not yet giving complementary value.

***Regulatory uncertainty.*** Regulatory uncertainty makes investors hesitant to inject significant capital into the industry, further impeding commercialisation prospects. Stability in regulation will provide stability for industry. In Europe, policy uncertainty on the future of biofuel policy post-2020 proves to be a bottleneck for investments. Whereas an incentive for advanced biofuels up to 2020 has been agreed upon by EU legislators, the situation post-2020 is uncertain.

***Technology-related barriers.*** The challenge for advanced biofuel production (at least for some technologies) is to achieve a scale-up of technologies, reaching high conversion efficiencies, ensuring

[5] ICCT 2013-12 - Measuring and addressing investment risk in the second generation biofuels industry

## 2 Cost profile of advanced biofuels

As described in the introduction, one of the main reasons why the market development of advanced biofuels has been slow is because when capital costs are added, production costs are high.

Conventional biofuels are essentially produced from sugars or starch (to produce ethanol) or vegetable oils (to produce biodiesel). Advanced biofuels are produced from agricultural and forestry residues, other residual biomass or energy crops and are more expensive to produce, in particular because the technology to convert these feedstock types to advanced biofuel is relatively more difficult and therefore more expensive compared to extracting, for example sugars from sugar beet, converting vegetable oil to conventional biodiesel or waste oils to biodiesel.

This chapter analyses the production costs of advanced biofuels and identifies which cost items are most relevant and what impact they have on the total cost profile. Since costs can differ depending on the chosen technology and feedstock, the analysis includes three specific biofuel production pathways:

- Cellulosic ethanol – using agricultural residues
- Fischer-Tropsch renewable diesel – using forestry residues
- Hydrotreated pyrolysis oil (HPO) – using forestry residues

These technologies are described in the text box below.

**Box 2 – description of advanced biofuel pathways for which production costs are estimated**

***Cellulosic ethanol.*** Lignocellulose consists of lignin, cellulose and hemicellulose, the exact composition differs per type of feedstock. The cellulose and hemicellulose are effectively poly-sugars which can be hydrolysed (broken-up) into mono-sugars (this is also called saccharification, literally conversion into sugars). These mono-sugars can be fermented to yield ethanol. Different technologies are under development for the hydrolysis step. These include *hydrothermal pre-treatment* (chemical free, steam pre-treatment followed by enzymatic hydrolysis) as used by Beta Renewables (Italy), and Clariant (USA) and Inbicon (Denmark), and *thermo-chemical pre-treatment* (dilute ammonia pre-treatment followed by enzymatic hydrolysis) as used by Abengoa (USA) and Dupont (USA). Several different types of sugars are produced (namely C5 and C6 sugars), which are then fermented into ethanol (most fermentation processes convert C6 sugars although C5 sugars can also be fermented simultaneously by some processes). The fermentation can take place in a separate reactor, or (partially) in the same reactor as the hydrolysis step. The reactor set-up depends amongst others on the enzyme technology available and the value of co-products. The lignin is not converted in the process, but can be used in animal feed or to produce power and steam (either on-site or at an external facility).

***Fischer-Tropsch (FT) renewable diesel based on wood.*** Solid biomass, such as wood and wood residues can be gasified to produce a synthesis gas. Gasification is a thermal process occurring with a shortage of oxygen, so that the material is not combusted, but rather disintegrates into specific small molecules, mainly carbon monoxide and hydrogen. This synthesis gas can then be chemically converted to a hydrocarbon product, using a so-called Fischer-Tropsch catalysis. The Fischer-Tropsch catalysis produces carbon chains of various lengths, which can subsequently be cracked into chains of the preferred length alike diesel or kerosene. The process involves a gasifier operating at high temperatures, i.e. ranging from 750 – 1000 °C. The Fischer-Tropsch reaction takes place at elevated pressure (10 - 60 bar) and temperatures (200 - 300 °C), which necessitates that the gas is cooled to room temperature in-between. The process also involves complex gas cleaning steps, to remove tars, and alkali and halogens from the gas that could poison the catalyst. Commercial production of Fischer-Tropsch renewable diesel from wood has been tried by several companies and consortia. So far, it has proven difficult to bring the technology to commercial scale.

***Hydrotreated pyrolysis oil.*** Wood and other lignocellulose material can be converted directly in an oil by means of (fast) pyrolysis. This is a thermal process with limited oxygen, falling in between combustion and gasification in terms of reaction temperature and outcome. A few companies are implementing the process on a commercial scale to produce crude pyrolysis oil. Ensyn operates a commercial facility in Ontario, Canada since 2014 to produce pyrolysis oil for industrial heat and another commercial facility by Empyro-BTG produces pyrolysis oil for electricity and industrial heat in the Netherlands since 2015. Different to vegetable oils, pyrolysis oil contains a few hundred different chemical components. For application in the transport sector the crude pyrolysis oil needs further upgrading either by hydrotreatment in a dedicated facility or be fed as co-feed with petroleum oils in refineries (FCC reactors). The hydrotreatment route can consist of two or three steps of stabilisation and catalytic hydrotreatment. These steps separate water from pyrolysis oil, remove oxygen, nitrogen, sulphur and saturate olefins and certain aromatics. The result is Hydrogenated pyrolysis oil or HPO that can be blended directly with fossil diesel, or a mix of diesel and petrol when resulting from hydrotreatment and distillation in fossil refineries. Hydrotreated pyrolysis oil can be used above the blend wall.

## 2.1 Build-up of cost profile and quantification approach

**Cost estimation approach cellulosic ethanol and Fischer-Tropsch renewable diesel**
Production costs for cellulosic ethanol and Fischer-Tropsch renewable diesel are estimated in euros per tonne of production using an MS Excel cost model, which also calculates the estimated payback time of production installations. The model contains some generic assumptions, for example on production plant life time and investment pay-back period, as well as some assumptions specific for each of the pathways, for example the capital costs (Capex)[6], operational costs (Opex) and plant performance data.

Generally, the first plant(s) built for a certain technology will be more expensive than subsequent plants. It is therefore important to differentiate between *first-of-a-kind* (FOAK) and *nth-of-a-kind* (NOAK) plants, the latter assuming that the pathway is technology mature. This study estimates the production costs for NOAK plants, which means that some assumptions for future cost and efficiency improvements are made. However, it should be highlighted that there is an added degree of uncertainty in estimating NOAK costs given the limited cost data that is currently available for FOAK plants.

**Cost items included**
The table below shows the main Capex and Opex cost items included in the cost estimation.

**Table 1 Overview of the Capex and Opex cost items included in the cost estimation**

| Capex costs | Opex costs |
|---|---|
| **Inside Battery Limits (ISBL)** | **Fixed costs** |
| Plant equipment (including piping, instrumentation) | Salary costs (including overheads) |
| Installation | Plant maintenance |
| On-site energy generation | Insurance & Property taxes |
| Storage (feedstock and fuel) | License fees |
| | |
| **Outside Battery Limits (OSBL)** | **Variable costs** |
| Permitting and legal compliance | Feedstock |
| Site preparation | Utilities (electricity, natural gas, water) |
| Logistics | Chemicals (including catalysts, enzymes) |

6 We assume that installations are built at existing industrial sites with existing transport links (i.e. any infrastructure costs are not taken into account).

| Capex costs | Opex costs |
| --- | --- |
| | Waste disposal |

**Main assumptions, data sources and uncertainties**

Modelling data was primarily informed through an extensive interview process with industry, coupled with literature review and available market information. A number of companies were prepared to provide us with detailed data. The cellulosic ethanol pathway data were more readily available and based on the detailed feedback provided by three companies. This reflects the fact that this pathway is relatively more mature compared to the other two pathways.

Standard assumptions for common parameters such as feedstock costs, fuel and utility prices were used to ensure consistency between the pathways (see Appendix). It should be noted that we assume projects to be mainly externally financed. This is <u>not</u> how most projects are financed in the EU currently (see the next chapter under 'Self-financing') but is likely to be the most widely used financing model in an expanding market. Our assumption leads to relatively high financing costs compared to own investments. We assume facilities will be located in those parts of the EU where feedstock costs are relatively low, still having good transport links.

It should be highlighted that there are some uncertainties regarding the data used in the cost modelling, largely a consequence of the limited data that is currently available. As such, the modelling results should be assessed in this light and treated as *indicative* rather than *absolute*.

The impact of data uncertainty was explored for a number of key parameters (capex, feedstock cost, interest rates for debt and equity), using a so-called 'sensitivity' analysis.

**Cost estimation of Hydrotreated pyrolysis oil**

Some commercial pyrolysis oil production projects exist in the US (Ensyn) and the Netherlands (Empyro-BTG). Cost estimates for this process are available. However, the upgrading of pyrolysis oil to a drop-in transport biofuel (Hydrotreated pyrolysis oil or HPO) does not yet take place at commercial scale and no reliable estimates could be collected from companies. Costs for both pyrolysis oil production and the upgrading to HPO are taken from a study by Pacific Northwest National Laboratory (PNNL) for the US Department of Energy, published in March 2015.[7] This study estimates production costs for a large NOAK plant producing HPO, both as renewable petrol and diesel in a 48% to 52% split and with a 10% internal rate of return and based on the 2014 state of technology. It is assumed that woody biomass is used at a cost of 88 EUR/dry tonne.[8] The estimation of revenues is based on fuel sales prices, with excess electricity and heat from pyrolysis production assumed to be used as process fuel in the upgrading phases instead of being sold. The study shows that between 2009 and 2014 HPO conversion costs decreased threefold, with further cost decreases

[7] Jones, Snowden-Swan, Meyer et al. (Pacific Northwest National Laboratory), Fast Pyrolysis and Hydrotreating: 2014 State of Technology R&D and Projections to 2017 (2015).

[8] The study mentions a feedstock cost of $101.45/dry tonne which is €88 at the exchange rate of 25 August 2015.

expected in the coming years. Most progress has been made in reducing costs for upgrading the pyrolysis oil to a transport fuel.

## 2.2 Cost profile results and analysis

The table below summarises the modelling outputs for the NOAK scenario, indicating the 'Payback term' and 'Cost of production', which are defined as:

- Payback term: number of years to 'payback' the original investment (i.e. the number of years needed for a company to receive net cash inflows that aggregate to the amount of an initial cash investment); and:
- Cost of production: the total of all costs (i.e. Opex and interest payments) divided by the total biofuel production over the plant lifetime.

The results factor in a 'double counting premium'. Biofuels produced from waste, residue or (ligno)cellulose feedstocks count twice towards targets in the EU, meaning that only half of the actual quantity of biofuel is required for fuel suppliers to meet their blending obligations. The double counting premium is the difference between the price of conventional ethanol and petrol and we assume that this premium largely ends up with the fuel supplier rather than with the biofuel producer, while the extent to which this happens is the result of a negotiation process between the fuel supplier and biofuel producer. For the purpose of this study we assume that 25% of the premium will be passed on from fuel supplier to biofuel producer. The cellulosic ethanol pathway also assumes that surplus electricity is exported to the grid.

**Table 2 Cost modelling results showing the CAPEX, total cost of production and payback term. Costs and revenues are estimated over a 20-year plant lifetime.**

| Pathway | Capital cost per facility (mln euro) | Capacity (ktonne) | Production costs (EUR/tonne) | Revenues (EUR/tonne) | Payback term (years) |
|---|---|---|---|---|---|
| Cellulosic ethanol | 100 | 55 | 750 | 1,004 | 8 |
| Fischer-Tropsch renewable diesel | 385 | 82 (14 ethanol) | 1,315 | 1,003 | >20 |
| Hydrotreated pyrolysis oil | - | 310 (149 petrol + 161 diesel) | 1,647 | 971 | >20 |

Cost estimations show significant differences between the three pathways. **Production costs for cellulosic ethanol are relatively low with 750 EUR/tonne**. This is the estimated cost for a next generation plant (NOAK). **Costs for first generation** plant (FOAK) are **considerably higher at around 1,000 EUR/tonne**. This means that today production costs are considerably higher than the market price of conventional ethanol which is currently sold to fuel suppliers for an average price of 750 EUR/tonne in the EU also higher than the current ethanol price with a double counting premium of 761 EUR/tonne (11 euro additional value from 25% double counting premium, price would be 794 EUR/tonne in case the full double counting premium would be passed on the biofuel producer). Some additional revenues are generated through the sale of excess electricity and total average revenues over the 20-year assumed plant lifetime are 1,004 EUR/tonne. These cost estimates show that a FOAK cellulosic ethanol plant is not likely to be economically viable without specific additional policy incentives. It also shows that a NOAK plant probably can be economically viable, and the additional cost of specific policy incentives for advanced biofuels will decrease.

Estimated cost of production for Fischer-Tropsch renewable diesel and HPO are estimated to be currently significantly higher, although costs for HPO have come down significantly in recent years and further reductions are expected. PNNL estimates that total HPO production costs for a NOAK plant will fall to around 1,100 EUR/tonne in 2017. Estimated payback term varies from over twenty years for Fischer-Tropsch renewable diesel and HPO to an estimated eight years for cellulosic ethanol. Based on these estimations it is likely that cellulosic ethanol will attract most interest from investors in coming years and future investments in Fischer-Tropsch renewable diesel and HPO require further cost reductions.

There are a number of reasons for the differences in production costs between cellulosic ethanol and the two other pathways. Firstly, the capex cost structures for the three pathways vary significantly. The Fischer-Tropsch renewable diesel process is relatively more complex (involving feedstock gasification and fuel synthesis) and therefore capital intensive, while the cellulosic ethanol process is to some extent based on the existing technology for 1st generation biofuel production and involves less extreme process conditions (lower temperatures and pressures). As for HPO, pyrolysis oil production is relatively inexpensive but its hydrotreatment to produce a biofuel is expensive and technically challenging. Secondly, the cellulosic ethanol pathway assumes that the electricity requirements are fully met through on-site generation (for example, through the combustion of lignin) and furthermore that excess electricity from cellulosic ethanol production is exported to the grid. In contrast, for Fischer-Tropsch renewable diesel only 50% of the total electricity requirements are assumed to be met through on-site generation. This increases the revenue for the cellulosic ethanol pathway, whilst also reducing Opex costs and therefore resulting in a lower payback term.

What do the calculated costs tell us about the carbon abatement costs of the various pathways? In order to estimate this we first compare the cost of replacing 1 tonne of fossil petrol or diesel by the equivalent quantity of biofuel based on energy content and subsequently calculate the carbon abatement cost based on the notion that a tonne of fossil fuel emits 3.6 tonnes of $CO_2$.

Replacing one tonne of fossil petrol fuel requires 1.6 tonnes of cellulosic ethanol and replacing a tonne of fossil diesel requires 1 tonne of FT biodiesel or HPO. Assuming an 8% producer margin on top of the calculated production costs of the three biofuel pathways, the cost of 1.6 tonne of cellulosic ethanol would be €1,296, which is 591 EUR more than the assumed cost of petrol of 705 EUR/tonne. The additional cost of replacing fossil diesel (assuming a diesel price of 669 EUR/tonne) by FT diesel and HPO stands at 751 EUR/tonne and 1,110 EUR/tonne respectively. When divided by a factor 3.6, the carbon abatement costs for the three pathways are 164 EUR/tonne $CO_2$ for cellulosic ethanol, 209 EUR/tonne $CO_2$ for FT biodiesel and 308 EUR/tonne $CO_2$ for HPO.

## 2.3 Assessing the impact of separate cost items on total production costs

The impact on the cost of production was assessed by varying the Capex cost, feedstock cost and interest rate levels. One parameter was varied at a time, while keeping all other parameter values fixed. The graphs below show the impact that higher or lower costs per individual cost items have on the overall cost profile per biofuel pathway.

The analysis highlights how the economic case is mostly dependent on the Capex and feedstock costs for all pathways. However, for the Fischer-Tropsch renewable diesel pathway even with a 50% reduction for these parameters (leading to an assumed 6% financing cost on debt and 5% on equity) the cost of production is still estimated to be over 1,000 EUR/tonne. The interest rate level, is still clearly an important factor in the overall economic case, but has relatively less of an impact compared to Capex and feedstock costs.

The analysis is done for cellulosic ethanol and  Fischer-Tropsch renewable diesel since for these pathways we have complete datasets. Our HPO cost estimation is based on the PNNL 2015 study, which specifies individual cost items but does not give the full list of parameter values.

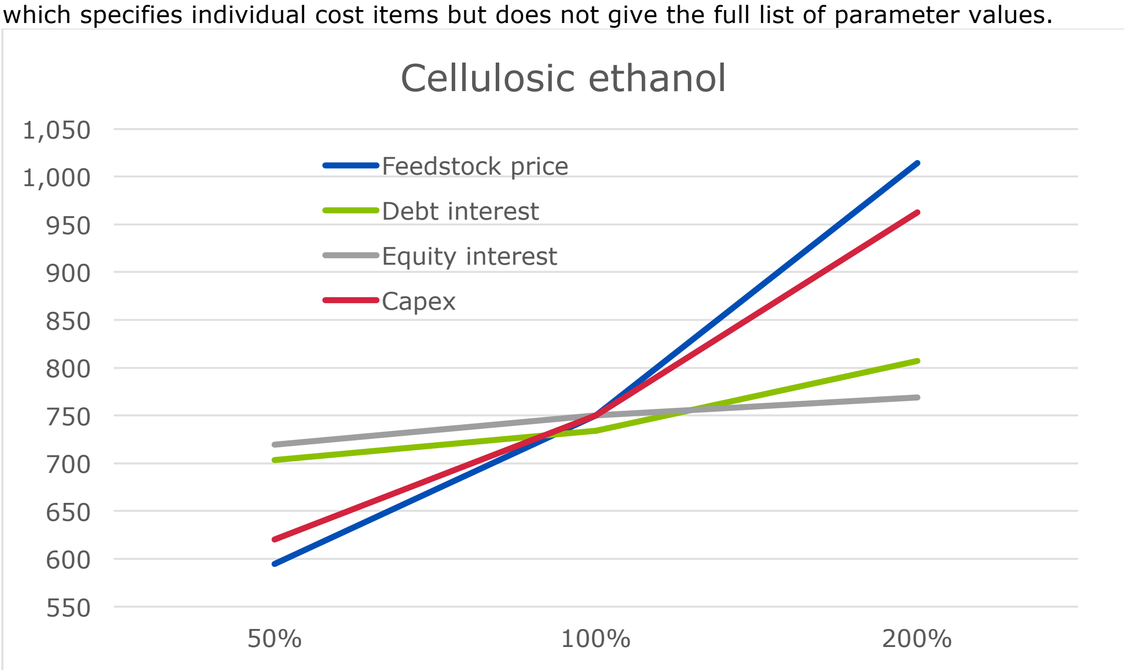


**Figure 1 Analysis of the impacts on cost of production for cellulosic ethanol. The 'base case' assumes a Feedstock price of €65/t, Debt interest of 12%, Equity interest of 10% and a Capex of €101M.**

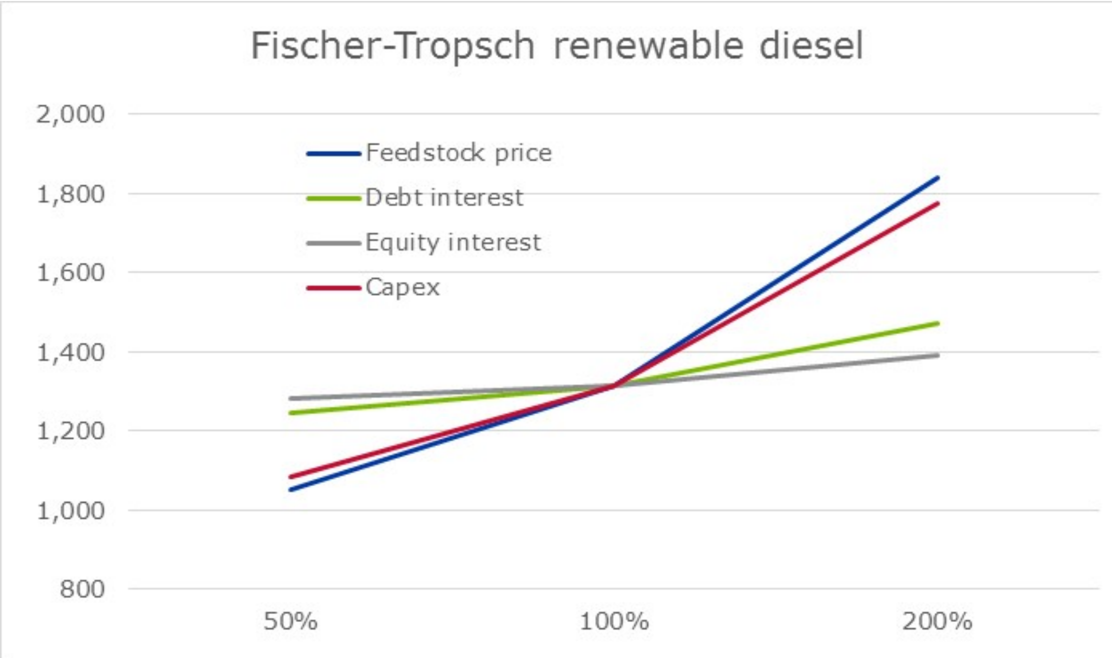


**Figure 2 Analysis of the impacts on cost of production for Fischer-Tropsch renewable diesel. The 'base case' assumes a Feedstock price of 50 EUR/t, Debt interest of 12%, Equity interest of 10% and a Capex of €385M.**

## 2.4 Conclusions

We estimated production costs for three biofuel pathways: cellulosic ethanol produced from agricultural residues, Fischer-Tropsch renewable diesel produced from woody biomass and Hydrotreated Pyrolysis Oil produced from woody biomass. Estimated costs for cellulosic ethanol and FT renewable diesel produced in next generation commercial facilities (nth-of-a-kind, NOAK) are modelled using assumptions (see Appendix) and data obtained from various sources. A cost estimate for Hydrotreated pyrolysis oil produced in a NOAK installation is based on a study by PNNL published in March 2015.

We estimate that production costs for a next generation commercial scale cellulosic ethanol can be as low as 750 EUR/tonne, whereas costs for a current generation plant (FOAK) stand at around 1,000 EUR/tonne. These figures do not include margins for biofuel producers. Total average revenues are estimated to be 1,004 EUR/tonne including an assumed double counting premium for the biofuel producer of 25% of the theoretical double counting premium of the difference between the price of conventional ethanol and petrol. When comparing costs with revenues it becomes clear that cellulosic ethanol is currently not economically viable without additional policy incentives.

Pyrolysis oil can be used as a transport fuel when hydrotreated (resulting in Hydrotreated pyrolysis oil or HPO) or when directly used in the refinery fuel production. Both routes are not yet implemented at commercial scale, making it difficult to accurately estimate total production costs. PNNL estimates

HPO production costs to stand at 1,647 EUR/tonne. While this means that today it is difficult to produce HPO at commercial scale, the PNNL study shows that significant cost reductions have been achieved in recent years and if this trend continues, costs will have come down to 1,100 EUR/tonne in 2017 and lower costs in subsequent years. This means that HPO might start to play a role at commercial scale after 2020. As HPO, Fischer-Tropsch renewable diesel is thought to be expensive, with an estimated production cost for a NOAK plant of 1,315 EUR/tonne, which is double the market price of fossil diesel. Also for this pathway cost reductions are needed to make the technology attractive for investors. We do note that only a few reliable cost data sources for Fischer-Tropsch renewable diesel are available, meaning that significant uncertainties remain for the results for this pathway.

The analysis also shows that capital costs and feedstock costs have the largest impact on the total overall production costs and that the impact of financing costs is relatively low.

Based on our production costs estimates it can be concluded firstly that of the three pathways cellulosic ethanol seems most attractive for investors and secondly that additional policy incentives are required to grow the market for advanced biofuels beyond the 'double counting' provision currently in place in the EU.

# 3 Assessment of financing options

Encouraging private sector investment in advanced biofuels facilities is a key challenge for the sector. Private sector investors vary greatly in terms of how they operate, the likely sums of capital they are willing to invest, the time on the path to commercialisation that any particular investor deems an investment appropriate and relevant, and in their general appetite for risk.

Venture capitalists (VCs), for example, want to invest in a company, and then sell their ownership share a few years later for what they hope will be a large profit ("buy and sell"). VCs have a great appetite for risk and only expect one out of ten investments to deliver exceptional returns (on average, three investments will fail, six will deliver ~4%–6%, and one will deliver returns greater than 10%). By contrast, any source of capital using pension fund monies will want to buy into a secure investment, and hold that investment for many years in the expectation that it will provide returns comparable to elsewhere in the market ("buy and hold").

Below we provide an overview of the market's main financing options: angel investors, commercial banks, venture capital, initial public offering, private equity/merchant banks, traditional project finance, sovereign wealth funds, investment banks, project bonds market, large corporate strategics and "self-financed projects". Each of these types of financing are described in general and their relevance for early stage advanced biofuels commercialisation is assessed.

It should be noted that although these are presented as separate discrete options, it is possible that in reality a combination or "stack" of financing options could be deployed.[9] For example, in addition to the capital that the project sponsor/proponent is contributing (investors will want to see proponent "skin-in-the-game", i.e. a minimum share of own investment) an Investment Bank (see below) may bring together a combination of private equity, venture capital, bond financing, export development bank loans, and/or a government loan guarantee to complete the necessary capital stack for a project. As one can imagine, however, the transaction costs of putting together such a financing package can be considerable, and would normally only be attractive to investors if all the risks and uncertainties were properly allocated. In general all risks need to be allocated before being able to reach a financial close[10]. If not the project will not continue, or the financing cost will increase.

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[9] A 'capital stack' is a compilation of the various sources of capital and financial instruments that are brought together to enable the project to be financed. A capital stack will usually involve both debt and equity, and can include equity from the project proponent, debt from a lender, monies from a strategic investor (debt and/or equity), the public markets (if the company is public), and government grants and loans, and/or loan guarantees.

[10] Ideally, all risks and uncertainties have been properly allocated by the project proponent, and can be managed by those parties best able/most qualified to manage them. (For example, feedstock risk should be assumed by the growers/farmers; construction completion risk should be assumed by the EPC contractor - with penalties for late completion.)

## 3.1 Angel investors

**General description**

Angel Investors are typically affluent individuals or groups of individuals (sometimes family members) who provide start-up capital (seed capital) to a new business or start-up company. In return, the angel will receive equity, or some form of ownership in the start-up.

**Investment 'sweet spot'[11]**

Funds can sometimes be in the millions, but not hundreds of millions.

**General risk tolerance**

Often high, but funds not sufficient for investment in large scale plants.

**Requirement for investment**

In many cases, if the angel investor is receiving equity, there is no expectation of immediate high returns on investment. In the case of family members providing mentoring, there may be no expectation there will be any long term returns

**Invest in early stage advanced biofuels commercialisation?**

**No.** Angel investors would invest in the launch of a new company, and perhaps in Research & Development, but generally not in high capex commercialisation projects.

## 3.2 Traditional lenders / Commercial banks

**General description**

Traditional lenders/Commercial banks (likely the project sponsor's local banker) typically provide small value loans, for example, for Research & Development.

**Investment 'sweet spot'**

Amounts are insufficient to build a commercial plant, and any loans often depend on prior bank/client relationship. For Commercial banks it is important that the prospective borrower has an established track record of past repayments, to know what their net worth is and whether there are sufficient company assets in case of project (or company) default.
(Note that advanced biofuels projects which, because of the nature of the transportation fuels market are unable to secure long term offtake contracts at a fixed price, are not comparable to wind and solar projects which in some cases have attracted traditional lenders, because offtake risk is not a factor.)

**General risk tolerance**

[11] The optimal balance between costs and benefits

Low risk tolerance with preference for low capex projects.

**Requirement for investment**
Strong balance sheet and company collateral. How do the borrowers assets compare to the risk of non-repayment?

**Invest in early stage advanced biofuels commercialisation?**
**No.** Biofuels firms do not have sufficient track record or strong balance sheets for large conventional commercial loans.

## 3.3 Venture Capital (VC)

**General description**
Venture Capital (VC) is private equity money provided by investors to early-stage, high risk startup companies and entrepreneurs. The VC (who can be an individual or a consolidated capital fund) will earn its financial return by taking an ownership (equity) position in the companies it invests in. Information Technology or the biotechnology sectors are good examples where VC funds have been invested.

Typically, VC investments occur after a company has already received early investment or "seed funding" from friends, family, their local banker, angel investors, or perhaps even crowd funding. The first round of VC funding is referred to as "Series A." The goal of the VC is to generate a return when the start-up has a significant event such as selling the company or going public (IPO). VC funds are attractive to start-ups who have limited operating history and are too small to raise capital in the public or debt markets.

**Investment 'sweet spot'**
A VCs initial investment (or, first round of funding), is referred to as "Series A." This amount can be anywhere from $100k-1m. Subsequent rounds (Series B) range from $1–20m, while later rounds, if the VC fund can afford it, could be in the range of $20-100m range.

**General risk tolerance**
High risk tolerance, but as noted above, only one in ten investments is expected to exceed average market returns, and three of the ten are expected to fail outright.

**Requirement for investment**
Likelihood of high rates of return >10x. 3 to 8 year exit strategy.

**Invest in early stage advanced biofuels commercialisation?**
**No** – unless part of a syndicate. Typically invest at an earlier, pre-commercial stage

## 3.4 IPO / Going public

**General description**
IPO (or initial public offering) represents a private company's first foray into the public markets to raise capital through the sale of shares of stock. IPOs are commonly issued by small to medium sized privately held companies seeking money to expand their business, and possibly to provide monetary returns to the firm's early private investors (large private companies seeking to become publically traded can also issue IPOs). After the IPO, shares trade freely in the open market. Before going to the market with an offering, a company should seek expert advice (often from an investment banker) as to best share price, and the appropriate time to go to market. This process transforms a private company into a public company with all the associated costs and financial disclosures. There have been a few IPOs related to investment in biofuels in the last six years, these investments mostly performed badly. IPO is not a strategy for raising capital for first-of-kind commercial plant unless a project is really capital light.

**Investment 'sweet spot'**
The company, and in this case, the project sponsor, is often seeking to raise \$100m+. The project should be "capital light" (i.e. low capex). Those seeking to go public need to assess whether the current IPO market is likely to respond to the offering.

**General risk tolerance**
Not relevant. (The company going public risks a failed IPO; or, if the IPO succeeds in raising sufficient funds, investors risk having invested in a stock whose value goes down and potentially fails.)

**Requirement for investment**
Mid-double digit returns (~15%) to attract investors.

**Invest in early stage advanced biofuels commercialisation?**
**Possibly, but unlikely** – it is doubtful whether the IPO will raise sufficient funds to support both ongoing company operations, and the financing of a commercial plant.

## 3.5 Private Equity / Merchant banks

**General description**
Merchant Banks are institutions that provide money to companies in return for share equity or ownership in that company rather than in the form of loans. Typically, merchant banks bridge the gap between venture capital and an IPO. That is, they offer financial services to smaller and medium-sized companies that are too big for venture capital firms, but too small to be of interest to the IPO market. The nature of the private equity investment is negotiated between the parties. Merchant banks will often take on a large portion of ownership if a company is believed to have strong potential for growth. Since they own shares in the companies in which they invest, merchant banks usually

also provide advice and services to these firms at the corporate level. Both commercial banks and investment banks may engage in merchant banking activities.

**Investment 'sweet spot'**
Amounts can range from $20-100m+. Company selling equity must be operational, not a start-up.

**General risk tolerance**
Low to medium risk tolerance.

**Requirement for investment**
Equity or ownership in the company.

**Invest in early stage advanced biofuels commercialisation?**
**Unlikely** - only if project sponsor and technology have a proven track record.

## 3.6 Traditional project finance

**General description**
**Project Finance** is finance for a specific project – a power station, a pipeline, a mine – wherein debt (the loan) is repaid from the cash-flow of that particular project. As such, the lender will look to what assets and what revenue the project will have, and assess whether or not those assets will be sufficient to first secure, and then service the loan. In this type of financing (unlike with more traditional borrowing), the lender has no recourse to any non-project related assets of the borrower or the project sponsor. That is, the project financier cannot "reach back" to a parent or project sponsor company to repay the loan if the project does not succeed. Since, if the project fails in whole or in part, the financiers stand to lose money, and since the loan can only be repaid once the project is operational and generating cash flow, risk minimisation is essential to project finance, and identification and allocation of every risk associated with the project is critical.

**Investment 'sweet spot'**
Large projects over $50m-2billion.

**General risk tolerance**
Low risk tolerance

**Requirement for investment**
Track record – proven technology; prefer B+ credit rating.

**Invest in early stage advanced biofuels commercialisation?**
**No.** These projects are not "investment grade." They have technology risk and do not have a credit worthy offtake. Note that while in today's world advanced biofuels projects are not considered investment grade, there may come a time when such projects can meet that requirement. This is less

about "how many plants has the proponent built to date," and more about the degree to which all uncertainties have been removed. Once there is no technology, feedstock, offtake, construction completion, performance, and, most importantly, policy risk, traditional project finance will become a more viable option.

## 3.7 Sovereign Wealth Funds

**General description**
Sovereign Wealth Funds are State-owned investment funds established from one or more of a country's balance of payment surpluses, foreign currency deposits, pension investments, oil funds, resource exports, sale of government assets, fiscal surpluses, etc. These funds are assets of the sovereign nation, and can take the form of bonds, stocks, property, etc. held in both domestic and foreign currencies. The funds are a mechanism for managing the national savings of a country for the purposes of investment. Funds may be managed by central banks, for example. Some funds invest in domestic industries. Globally, the largest sovereign wealth funds exist in China, United Arab Emirates, Norway, Saudi Arabia, Kuwait, and Singapore.

**Investment 'sweet spot'**
Investments in the hundreds of millions. Looking for investments that will have a "material impact" and high returns - not one-offs.

**General risk tolerance**
Low risk tolerance.

**Requirement for investment**
Mostly equity so looking for safe, substantial returns.

**Invest in early stage advanced biofuels commercialisation?**
**No.** The advanced biofuels sector does not currently meet the test of "material impact."

## 3.8 Investment Banks

**General description**
Investment Banks are facilitators who bring together other investors` money in an effort to build the necessary capital needed by a business entity to build a project. Unlike Merchant Banks (see above), investment banks are more typically focused on larger firms. Both debt and equity instruments may be used, but investment banks do not take deposits, or have their own source of funds. They facilitate financial transactions and also provide research and financial consulting services to companies. The provision of investment banking services requires a government issued license.

**Investment 'sweet spot'**
Transaction costs mean interest is mainly in large projects - $100m+. Investment Banks do not have their own source of funds, but are facilitators who bring together other investors` money in an effort to realise the project. So the sweet spot will depend largely on who the Investment Bank brings to the table.

**General risk tolerance**
Not relevant – is up to the individual investors the Investment Bank brings to the table. Looking forward, however, while in today's world it is very challenging to raise capital for advanced biofuels projects, it will become easier over time for Investment Banks to put together project financing deals once all risks have been eliminated or properly allocated. Of the various risks including technology, feedstock, and offtake, the most important risk for investors is government policy uncertainty, and the associated fear of stranded assets. Once this uncertainty is removed, and the advanced biofuels market is more mature, putting together a project capital stack will become a more viable option.

**Requirement for investment**
Depends on who the Investment Bank brings to the table, but returns need to be competitive with the market.

**Invest in early stage advanced biofuels commercialisation?**
**Possibly** if risks can be off-loaded and managed. A government loan guarantee will help.

## 3.9 Project bond market

**General description**
Project bonds are an alternative debt financing mechanism more recently used for infrastructure projects. Conventionally, banks have financed such infrastructure deals. But given recent higher costs and resulting higher capital requirements of bank financing, project developers have been looking more to the institutional bond market to reduce the project funding cost and thereby improve their project rate of return. This is a specialised niche requiring credit worthy project sponsors. The use of project bonds as a funding mechanism will be unattractive to investors with a low risk appetite – especially if there is any associated construction completion or technology risk.

**Investment 'sweet spot'**
Typically $50m-1billion. Usually for infrastructure projects. A specialised niche requiring credit worthy project sponsors, and (in the energy space) an offtake contract.

**General risk tolerance**
Low risk tolerance if any technology risk. Look to credit worthiness of project sponsor.

**Requirement for investment**
3 – 9% on debt.

**Invest in early stage advanced biofuels commercialisation?**
**No.** Not typically interested in technology investments. However, once the market for advanced biofuels becomes mature (in an environment of policy stability), and project sponsors are credit worthy with projects that are investment grade, the use of project bonds as a funding mechanism will become more viable.

## 3.10 Large corporate strategics

**General description**
Corporate Strategics are large corporations (Royal Dutch Shell, British Petroleum, Coca Cola, for example) that invest in innovative technologies for a variety of strategic reasons where it has been determined that such an investment could be in the best long term interest of the Corporation. Such things as gaining a competitive edge, meeting government policy requirements or upcoming regulations, or Corporate Social Responsibility could force a large corporation to make a strategic decision to invest in innovation even if it is outside the Corporations core line of business.

**Investment 'sweet spot'**
Investment in new, non-core technology could range from $50-300m+. (Strategics' large capital budgets are mainly committed to core business seeking 20%+ ROI). Examples include Royal Dutch Shell, British Petroleum, Chevron.

**General risk tolerance**
Low to medium risk tolerance, but not keen on technology risk unless they own the Intellectual Property (IP).

**Requirement for investment**
More patient than Venture Capital (see above), but need returns capable of competing with core business (i.e. 20% ROI). May be willing to receive lower returns on a first plant if it appears that, in the medium to long term, there is an opportunity for widespread deployment and material impact on the Corporation's business. Not much interest in "one-offs."

**Invest in early stage advanced biofuels commercialisation?**
**Possibly** in an environment of stable government policy. Fear of "stranded assets" (from which investors cannot recover any losses) means need for "grandfathering" in the event of a change of government policy.

## 3.11 Self-financing

**General description**

Self-financing is not a common financial term, but refers to Corporate Strategics who go beyond just investing in innovation at the R&D stage, to investing their own capital from their own corporate balance sheets in first-of-kind commercial projects in a given technology area such as 2$^{nd}$ generation biofuels. Such project financing from within a corporation's own access to capital can sometimes be driven by government policy (as has been the case in cellulosic biofuels), and is often accompanied by a plan to sell technology licenses following completion of the first plant in an effort to recoup losses from having financed the initial commercial facility. This type of investment is often used for advanced biofuels today (e.g. Beta Renewables in the EU, DSM in Brazil and the US).

**Investment 'sweet spot'**

Projects to date have cost in the range of $100-600m. Large companies pay for their own projects using their own funds (balance sheet financing), hence the term "Self-financed." In some cases, the Corporate balance sheet of a Corporate Strategic is sufficiently large, and the credit rating of the Corporation high and sufficiently well established, that the company may be able to attract a government loan or loan guarantee as part of the overall project capital. In other cases, if the project returns are at least adequate (five year simple payback), a Corporate Strategic may not want to seek government program dollars, because "why would we if the returns are adequate." Examples to date include Abengoa, Beta Renewables, Dupont, Poet/DSM and Raizen/Iogen.

**General risk tolerance**

High for first-of-a-kind (FOAK) projects (especially if there is evidence of improved returns on future plants, and/or an opportunity to sell technology licenses).

**Requirement for investment**

Willing to take below market returns on the first project if subsequent projects, or customers for technology licenses are likely.

**Invest in early stage advanced biofuels commercialisation?**

**Yes** for FOAK projects. Many hope to recover losses from this first plant by selling technology licenses. May offer technology guarantees to said licensees.

## 3.12 Conclusions

Currently, advanced biofuel projects both in the EU and US have been mostly funded by companies themselves (Self-financing). This makes sense in a market with large regulatory and offtake risks, but in order to grow a thriving advanced biofuel industry at some point external investors will be needed to bring in more capital. In this study, eleven types of investors were identified that could play a role in funding advanced biofuel projects. In summary, of the eleven financing options reviewed, only "**Self-financing"** is identified as presenting a likely short term investment source for advanced biofuels. Self-financing means that large companies are prepared to invest their own capital not just in innovation at the R&D stage, but also in first-of-a-kind (FOAK) commercial projects. In many cases these companies are willing to take below market returns on a first of a kind project in the hope that any project losses will subsequently be recovered by selling technology licenses to other potential project developers.

Three external funding options, **Large Corporate Strategics[12], Investment Banks and Initial Public Offering[13],** are identified as possible investment sources under the right, and extremely optimal, conditions. Of these, Corporate Strategics seem the most likely if they can be persuaded that an investment in advanced biofuels is in their long term best interest, and that such an investment will eventually have a material impact on their business. It could be interesting to combine several financing options, so to reduce the risks for individual parties, e.g. a combination of strategic investors, industrial parties, venture capitalists, pension funds and government money. Of course it would be challenging and time consuming to assemble all pieces Such a combination (capital stack) could finance projects provided all the deals can come to a close at or near the same time. In all cases, whether Strategics, or some syndicated group that an Investment Bank is able to assemble, all investors are unlikely to proceed if there is a hint of government policy instability. Given the cost of first-of-a-kind advanced biofuels facilities, any perceived threat of stranded assets will discourage investors. Essentially, certainty is the mother of investment, both in terms of markets and government policies.

The remaining seven options are not considered relevant for investments in advanced biofuel plants. The reasons for this vary, but typically come down to the large size of the capital investment required, a lack of appetite for technology and therefore project risk, and a fear of future change of law. Also, since advanced biofuels projects and their sponsors do not have a proven business track record and typically lack a strong balance sheet, proposed projects are not considered "investment grade" (have sufficiently low risks to investors) by traditional providers of debt. In other words, the proposed project investment does not meet the minimum acceptable rate of return for investors.

As noted above, however, as more projects come on line and the advanced biofuels market matures, and as uncertainties, especially the risk of government policy change, are removed, it may become increasingly likely that an Investment Bank, for example, is able to pull together a collection or group of financing options to meet the capex needs of advanced biofuels projects, or that a Strategic investor, in an effort to reduce its environmental footprint, will finance a project because said project is now able, or close to able, to compete with other investment opportunities faced by the Corporation. It comes down to the elimination of risk and uncertainty.

A general observation on financing first of kind commercial plants is that it is more of an art than a science, no hard and fast rules apply. Investment bankers, for example, will look for creative ways to

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[12] Large companies with large balance sheets
[13] IPO represents a company's first foray into the public markets to raise capital through the sale of shares of stock. IPOs are commonly issued by small to medium sized companies seeking money to expand their business. After the IPO, shares trade freely in the open market.

put together the necessary capital to get a project built. People, groups, banks, entities that lend money want to be certain they are making a wise investment decision. Some lenders are prepared to take greater risks than others (have a higher "risk tolerance)," in which case their cost of capital may be lower than a lender who is highly risk averse and wants a high return for any risk (real or perceived) that the borrower is taking. So what works in one instance of a project capital raise, may not work in the next.

# 4 How policy measures can boost investments

High-tech advanced biofuels are currently not cost-competitive with conventional biofuels or with fossil fuels and thus require some form of policy support. Currently, the EU allows advanced biofuels to count twice towards national mandates.[14] While double counting led to a substantial increase in the production of biodiesel from used cooking oil and animal fats, it has hardly resulted in investments in cellulosic biofuels to date.[15] Double counting has proven insufficient as an incentive for cellulosic biofuels and thus additional policy support is needed to grow the market. Such support can stimulate investments in production capacity by reducing the risks identified in Barriers for advanced biofuel deployment.

This chapter assesses the extent to which various potential support measures effectively mitigate one or more of the risks from the perspective of an investor. We will assess the following policy measures:

- Energy-based mandate or blending obligation specific for advanced biofuels;
- Carbon intensity reduction mandate *(percentage of WTW fossil transport emission reduction to be achieved by blending advanced biofuels)*;
- Fiscal support measures, such as corporate tax reductions or waivers, fuel tax reductions or waivers, VAT reductions or waivers;
- Investment support measures, such as investment grants/subsidies, public loans, loan guarantees;

An incentive already in place is the use of biofuels in the EU ETS. Companies with an obligation under the ETS can use biofuels to fulfil their ETS obligation, with biofuels assuming to have zero greenhouse gas emissions. Consumption of a tonne of fossil petrol or diesel emits about 3.6 tonnes of CO2 per tonne of fuel consumed. Replacing this by FT biodiesel or Hydrotreated pyrolysis oil represents a value of €29 per tonne, assuming an ETS credit value of €8 per tonne. Replacing a tonne of fossil fuel by cellulosic ethanol generates a value of about €18 per tonne, due to its lower energy content. This is clearly insufficient to bridge the current cost-gap between advanced and conventional biofuels, let alone the cost gap with fossil fuels, even if for the purpose of ETS-compliance conventional biofuel would no longer generate credits. Due to the limited effectiveness of this support measure it is not discussed in more detail in this chapter.

The four selected policy measures are assessed as stand-alone measures as well as part of combinations of several measures. When assessing the effect of support measures, advanced biofuels are compared to fossil fuels rather than conventional biofuels because while today advanced biofuels

[14] EU Renewable Energy Directive (2009/28/EC) article 21(2)
[15] Most Member States allow the double counting of biodiesel produced from used cooking oil and animal fats. Whereas these feedstocks are generally considered to be residual feedstocks, they are not considered 'advanced biofuel' for the purpose of this study.

compete with conventional biofuels under national mandates, post-2020 the focus may be more on being able to compete with fossil fuels. The following assessment criteria are used:

1. Can it be expected that the measure creates a sufficiently large market for advanced biofuels? Does the measure reduce the risk that advanced biofuels cannot be sold to the market at a high enough price (reduce **offtake risk**)?

   Currently, market conditions for advanced biofuels are not attractive, mainly because they cannot compete with conventional biofuels and because insufficient specific incentives exist for advanced biofuels. Measures can reduce the offtake risk either by enabling advanced biofuels to compete with conventional biofuels in the same market or by fencing off a market for advanced biofuels, by measures that decrease advanced biofuel production costs or by measures that increase revenues. If a substantial market would be created specifically for advanced biofuels, the fuels could be sold at a high enough price and the offtake risk for investors would decrease. Other ways to
   Measures that have a direct impact on the creation of a market specifically for advanced biofuels, that decrease the production costs or increase revenues successfully contribute to reducing the offtake risk.

2. To what extent is the measure designed to be 'future proof' in the sense that it provides a degree of regulatory certainty for a sufficient period of time (reduce **regulatory risk**)?

   Until the moment at which advanced biofuels are cheaper than fossil fuels, regulatory support is required to secure a market share. Only a stable regulatory environment will create a stable investment climate in which investments will be made. It is clear that over time legislation can change and no full regulatory certainty exists. It is also clear that some measures are more likely to be changed than others. In our assessment we firstly assume that measures which require government budget paid for by tax payers are more likely to be amended than measures that are paid for by consumers with the cost 'hidden' in the non-tax part of the fuel price. Secondly, it will be assumed that measures that are taken at EU-level are more stable than measures taken by individual Member States. Finally, a high level of public support increases chances that measures will stay in place once introduced.

3. To what extent does the measure help to convince investors that the risks of investing in advanced biofuels are acceptable or that the amount of required private financing is decreased (reduce **financing risk**)?

   As stated in 3.12, investors look for an elimination of risk and uncertainty. The main reasons why investors are currently hesitant to invest in advanced biofuels is the high capital cost which make the product uncompetitive. Furthermore, no market is guaranteed for the product and a stable regulatory support system to create this market is also lacking. A policy measure helps to reduce the financing risk if it directly leads to a lowering of the total capital costs required, if it reduces the offtake risk and reduces the regulatory risk.

4. To what extent does the measure ensure that sufficient feedstock will be available at an acceptable price (reduce **feedstock risk**)?

   Advanced biofuels, including the specific pathways assessed in the previous chapter, are often based on wastes and residues as feedstocks. These feedstocks are potentially inexpensive as they currently have limited or low-value uses. Once more advanced biofuel capacity is built using a certain residue feedstock in a certain geographical area, the material can become increasingly scarce price and as a consequence the price of the feedstock is likely to increase. This is especially true for biomass with relatively local markets in regions with many competing uses for the material. Straw, for example, is usually traded within a 500 kilometre range and in areas where demand is high (e.g. the Netherlands) prices can reach €100/tonne, whereas in areas where demand is low and supply abundant (e.g. Ukraine), prices will generally be lower than €50/tonne. This means that large investments in straw-based ethanol in the Netherlands would bear a significant feedstock risk whereas risks are low if the same facilities are constructed in places where straw is abundantly available. Rising feedstock prices can be problematic even if a market share for advanced biofuels is secured by a specific mandate because under the mandate different biofuel production pathways using different feedstocks may compete against each other.

   It could be argued that higher biomass feedstock prices will provide an incentive to invest in yield increases and improved supply chain economics, leading to increased supply at lower costs, thereby (partly) offsetting the price increase triggered by higher demand for advanced biofuel feedstock. This mechanism is unlikely to work for residual biomass. Agricultural or forestry residues or other residual biomass typically have a low price per tonne compared to the main product and the development of new, higher yielding agricultural crop breeds during the last decades often led to a decrease in the quantity of agricultural residues because the lower the stems, the smaller the chance that stems break, leading to yield losses. An increase in residue prices is unlikely to reverse this trend. However, increased demand may improve the economics of energy crops that are produced specifically for the purpose of bioenergy including advanced biofuels. For these crops, an increase in demand from advanced biofuels can lead to improved crop economics and higher yields. It is thought for example that for the energy crop *Arundo donax* innovation and increased supply chain efficiency can result in a significant cost reductions.

   A policy measure that increase the consumption of advanced biofuels will not have a significant feedstock risk provided the biofuels are produced in locations where feedstocks are available in abundant quantities. use if located in an area with and increase the feedstock risk for residual biomass. This maybe a lesser concern for energy crops due to higher demand elasticity.

Another risk which investors face is the **technology risk**: the risk that the biofuel production technology will not function optimally at commercial scale. For this, we assume that it is difficult for governments to mitigate this type of technological risk. This is a risk that the market must deal with, it requires time and a level of market maturing to pick technological winners. The risk is not assessed separately here.

## 4.1 Mandate specific for advanced biofuels

Mandates can either be generic, applying to all types of biofuels (as is currently the case with most EU Member State mandates), or be specifically targeted towards advanced biofuels (as per the "non-binding" subtarget of 0.5% as introduced in the EU "ILUC Directive" and also the binding subtarget in Italy from 2018).[16]

A mandate can be either energy or volume based. Such a mandate will only have a positive impact on investments in advanced biofuels if a certain differentiation is made between conventional biofuels and advanced biofuels. Advanced biofuels are more expensive than conventional biofuels per unit of energy so fuel suppliers without policy interventions will generally use conventional biofuels to meet their blending obligation.

<u>Offtake risk</u>

A general energy mandate is ineffective to achieve this as it doesn't differentiate between relatively cheap conventional biofuels and more expensive advanced biofuels. Yet a specific energetic mandate for advanced biofuels can be meaningful because no competition with conventional biofuels exists under the mandate. However, a specific mandate or submandate will only help to create a market for the technologically advanced biofuels assessed in this study if they don't have to compete with cheaper, low-tech advanced biofuels such as UCOME (biodiesel produced from used cooking oil) and TME (biodiesel produced from animal fats). A well-designed mandate for advanced biofuels would reduce offtake risks for investors. Of course the introduction of a mandate for advanced biofuels will lead to a successful deployment of certain advanced pathways at the expense of other pathways that turn out to be too expensive. This means that the mandate will not automatically reduce the offtake risks for each of the advanced biofuel pathways, but will allow them to compete amongst each other with a guaranteed market for the most cost-competitive advanced biofuels. While it would not be wise to make a mandate technology-specific, a certain differentiation within the mandate might be beneficial in terms of reducing offtake risk. Looking at the large estimated differences in production costs between various pathways it might for example be good to differentiate between a separate mandate for cellulosic ethanol and a mandate for advanced renewable diesel.

A mandate provides investors with a certain value for advanced biofuels that will make the product interesting to invest in even though production costs are still higher than those of fossil fuels and conventional biofuels. This notion however only bears truth if (1) the market price of advanced biofuel can be predicted several years ahead, which is generally difficult (2) a substantial share of the

[16] Italy introduced in 2014 a binding submandate for advanced cellulosic biofuels with a mandated volume, starting at 1.2% of the total fuel mix in 2018, increasing to 1.6% in 2020 and 2% in 2022. Italy also decided to extend the overall biofuel mandate of 10% in 2020 to the same percentage in 2022.

price benefit of the mandate trickles down from the fuel supplier to the advanced biofuel producer and (3) the cost of non-compliance for obligated parties is sufficiently high. The latter means that a high buy-out or waiver price is required, sufficiently high to make investments in advanced biofuel capacity worthwhile.

**Box 3 – description of a buy-out possibility**

| |
|---|
| **Buy-out**. A buy-out is the possibility for obligated parties in a biofuel mandate to refrain from supplying their mandated physical amount of biofuel to the market and instead to pay a certain 'buy-out price' per unit of biofuel. Several EU Member States have such an option, which is called 'waiver credit' in the US context. |

The US has had a specific mandate for cellulosic ethanol in the RFS since several years, with a target set at 14 billion gallons of cellulosic ethanol in 2022 plus intermediate targets. This target should have significantly reduced the offtake risk. However, fuel suppliers as obligated parties soon found out that they would not actually need to blend this volume if the fuel wasn't there, they only need to buy waiver credits. It is actually not in their interest to support the biofuel industry, as it decreases their market size. Recently the obligated parties lobbied the EPA hard when the RIN price increased significantly (to $1-1.4) as blend wall was reached. This should have acted as signal to increase supply for fuel (e.g. through E85 implementation), but instead targets were adjusted.

Regulatory risk

As with any legislation, mandates can be changed or abolished. In this sense it is impossible to provide regulatory certainty for mandates. On the other hand, a specific mandate for advanced biofuels can be quite stable once put into legislation, as it requires a new political process with a parliamentary majority to abolish the mandate, which requires time and will not always be easy. The EU target for 10% renewable energy in transport in 2020 has been controversial once agreed upon in 2008 but it was kept in place and will be in place even though the contribution of conventional biofuels has been restricted to some extent recently. This example shows that a mandate can give a relatively high degree of regulatory certainty. What helps is if the mandate is embedded in a wider and generally accepted storyline which outlines the degree to which a country or group of countries aims to reduce transport greenhouse gas emissions, how this will be achieved, which role biofuels play and against which conditions. It is important that this storyline is accepted and actively promoted by civil society, industry and policy makers, each of them should feel ownership. The mandate can start small, for example 0.5% advanced biofuels and can gradually be increased to a more meaningful share of the total fuel mix. If society in general sees the benefit of having the submandate and actively supports it, politicians will not repeal or lower the mandate. When the mandate would be accompanied by a 'buy-out price'[17], this price should be high enough to prevent it from being an 'easy way out' for obligated parties.

In the case of the US mandate for cellulosic ethanol, no regulatory stability was provided as the mandate has been lowered several times since its introduction due to lack of available production. There are several reasons for this. Firstly, the mandate was not really a mandate but rather a target with a very low buy-out price, which meant that fuel suppliers did not need to buy advanced biofuels but instead buy waiver credits (see above). Also, the initial target is generally perceived being set at a rather high level of 14 billion gallon of cellulosic ethanol by 2022; maybe this level was too high for an emerging sector. Thirdly, the RFS was introduced mainly to promote energy security, a role that became less urgent with the surge in shale-oil. And finally, when US policy makers initially gave

[17] Possibility for fuel suppliers to pay a certain price instead of physically blending advanced biofuels into fuels they supply to the market. The price is relative to the quantity of biofuel they are obliged to blend. Such a 'buy-out' is introduced to prevent a situation in which fuel suppliers cannot meet their obligation because the quantity of biofuel available on the market is too limited. A buy-out can also be a mechanism to prevent the food-price impact of biofuels: if agricultural commodity prices rise above a certain level it will be cheaper to pay the buy-out price rather than to use crops to produce biofuels.

much political support to cellulosic biofuels, but soon the storyline for cellulosic biofuels weakened, partly under pressure from incumbent fuel suppliers who do not support biofuels.[18]

Financing risk

As stated above, a policy measure helps to reduce the financing risk if it directly leads to a lowering of capital costs required, if it reduces the offtake risk and reduces the regulatory risk. A mandate does not directly lower capital costs. It does however reduce the offtake risk and if the mandate is smartly designed and widely supported, the regulatory risk can be small as well. The value of the mandate for investors depends on the number of years the mandate cover: if a mandate is valid for the next five years only it is likely to be too short to allow investments to be paid back. If however a mandate is valid for ten years it may create a market for a sufficiently long period to allow investments to be paid back.

The value of a mandate for investors also depends on the level of the buy-out, if such an option is introduced. As stated above, the buy-out must not be too low, or else the market signal of the mandate will be ineffective. In fact, the buy-out should at the very least be higher than the estimated price difference between the production costs of advanced biofuel and the market price of fossil fuel, but in fact higher since investors want to make a reasonable margin and will discount some of the value of the mandate. Based on the costs presented in Cost profile of advanced biofuels and fuel prices in the Appendix it is safe to say that a buy-out should be higher than 100 EUR/tonne for cellulosic ethanol and much higher to not endanger investments in Fischer-Tropsch or HPO projects.

Feedstock risk

The question whether a feedstock risk occurs or not depends on the chosen production location (are feedstocks abundantly available or not) and in cases where a feedstock risk might occur, the risk can differ depending on whether the chosen feedstock is residual biomass or an energy crop. While it is not straightforward that a feedstock risk will indeed occur, the introduction of a mandate might lead to an increased feedstock risk mainly for residual biomass in areas where feedstock supply is short and might trigger improved crop economics for dedicated energy crops.

The table below summarises the assessment provided above for an **energy mandate**.

**Table 3 - Impact of a mandate in reducing investors' risks**

| Criteria | Assessment |
|---|---|
| Reduction of offtake risk | If binding, specific for advanced biofuels and with a high buy-out price |
| Reduction of regulatory risk | If embedded in a convincing and widely supported storyline |
| Reduction of financing risk | If valid for at least 10 years and with a high buy-out price |
| Reduction of feedstock risk | Increased risk when residual biomass is used in areas with limited feedstock availability, less or little risk for energy crops or in areas with abundant supply |

[18] http://insideclimatenews.org/news/20140210/oil-industrys-fight-kill-renewable-fuels%E2%80%94and-why-it-may-win

**Green: risk can be reduced, yellow: risk can be partly reduced or unclear whether risk will occur**

## 4.2 Carbon intensity reduction mandate

The EU already has a fuel carbon intensity reduction obligation as laid down in the Fuel Quality Directive (2009/30/EC) which obliges fuel suppliers to reduce well-to-wheel emissions of transport fuels by 6% in 2020. Biofuels are likely to play a large role in achieving the target and national mandates will be the most common way to provide the necessary volumes of biofuels. Germany is currently the only EU Member State that has implemented a carbon intensity reduction target or mandate at a national level. Fuel suppliers are obliged to sell biofuels to reduce their overall GHG emission by 3% in January 2015 increasing to 4.5% in 2017 and 7% in 2020. Since the German carbon intensity reduction target entered into force from 2015 onwards it is too early to tell what the effect of the measure is. German government agency BLE reports that the average greenhouse gas performance of biofuels did increase in the first quarter of 2015 compared to the same period in 2014.[19] It seems that this increase results mainly from biofuel producers calculating the actual GHG performance of their biofuels instead of using the standard emission values. It also appears that fuel suppliers request from biofuel producers to supply them with conventional biofuels that achieve at least 58% or 60% saving without a price premium and that biofuels with higher savings do not get a premium either. [20] There are no indications that so far the measure lead to increased consumption of cellulosic biofuels.

Offtake risk

Because advanced biofuels generally have a higher greenhouse gas saving than conventional biofuels a carbon intensity reduction mandate could provide an incentive for advanced biofuels. Advanced biofuels generally achieve greenhouse gas savings of about 75% to 95% compared to fossil fuels while most conventional biofuels can achieve around 60% saving, although the ILUC effect is likely to lower this achievement. This means that with a carbon intensity reduction mandate, advanced biofuels have an advantage of 25% or more over conventional biofuels and could in theory be sold at a higher price than conventional biofuels per unit of energy. At the moment in Germany there seems to be no premium for biofuels with a better greenhouse gas performance. This could be due to the fact that suppliers still have older contracts in place which will be replaced by new contracts in the near future. It's too early days to tell what the effect of the 'FQD approach' will be on the pricing of biofuels.

It is clear however that relatively cheap alternatives to conventional biofuel exist with high greenhouse gas savings, most notably biodiesel produced from used cooking oil or animal fats. It is likely that a carbon intensity reduction target will primarily drive an increased update of these cheaper alternatives, rather than advanced cellulosic biofuels.

[19] http://www.ble.de/DE/02_Kontrolle/05_NachhaltigeBiomasseherstellung/THG-EinsparungBiokraftstoffe.html?nn=2304706

[20] Interaction with the Verband Deutsche Biokraftstoffe (VDB)

For a carbon intensity reduction mandate to be successful in reducing the offtake risk for advanced biofuels there would need to be a specific share for advanced biofuels within the mandate, e.g. by requiring that at least 0.5% well-to-wheel emission reduction shall be achieved by the use of technologically advanced biofuels. This would reduce the offtake risk. Such a measure could be particularly effective of accompanied by measures that have a more direct impact on lowering CAPEX, such as investment support or a direct impact on increasing revenues such as a tax break.

Regulatory risk

As with an energy mandate, a carbon intensity reduction mandate can be changed meaning that some regulatory risks will remain but a convincing and widely accepted storyline could provide a sufficient degree of regulatory certainty. To ensure that investors are not taking any stranded asset risk, projects that get built during a mandated or carbon intensity reduction regime must be assured of grandfathering should some future government change the rules.

Financing risk

A smartly designed carbon intensity reduction mandate that is widely accepted and therefore more or less future proof can reduce the offtake risk and therefore also the financing risk. To ensure that investors are not taking any stranded asset risk, projects that get built during a mandated or carbon intensity reduction regime must be assured of grandfathering should some future government change the rules.

Feedstock risk

As discussed under the energy mandate in section 4.1, the question whether a feedstock risk will occur or not depends on the chosen production location and on whether residual biomass or energy crops are used. While it is not straightforward that a feedstock risk will indeed occur, the introduction of a policy measure that increases advanced biofuel production increases the feedstock risk for residual biomass and only in those areas where feedstock supply is short and might trigger improved crop economics for dedicated energy crops.

The table below summarises the assessment provided above for an **carbon intensity reduction mandate**.

**Table 4 - Impact of carbon intensity reduction mandate in reducing investors' risks**

| Criteria | Assessment |
|---|---|
| Reduction of offtake risk | If binding and specific for advanced biofuels |
| Reduction of regulatory risk | If embedded in a convincing and widely accepted storyline |
| Reduction of financing risk | If designed appropriately (i.e. "future proof") |
| Reduction of feedstock risk | Increased risk when residual biomass is used in areas with limited feedstock availability, less or little risk for energy crops or in areas with abundant supply |

**Green: risk can be reduced, yellow: risk can be partly reduced or unclear whether risk will occur**

## 4.3 Fiscal support measures

Governments can provide fiscal support by lowering or completely waiving fuel tax or VAT, which makes it more attractive for fuel suppliers to source and sell advanced biofuels. Fiscal support can be provided at national level. A high enough level of support per unit of fuel can be sufficient to create a market. Many EU Member States provided fiscal incentives for biofuels from the mid-2000s. A risk of fiscal support is that the total cost depends on the success of the policy measure: the more successful in achieving its aim the more costly the measure becomes. Some national tax incentives for biofuels in the EU proved to be too expensive from the perspective of governments or did not deliver the expected impact[21] and were abolished and replaced by mandates. Another possible reason why fiscal incentives may have been abolished is that in 2010/11 most Member States implemented the EU RED which meant that they had to ensure that a certain 10% of transport renewables was going to be supplied to the market by 2020 and mandates offer more certainty that this target would indeed be met. Sweden maintains a fiscal incentive up to today. Under the Energy Tax Act,[22] biofuels are eligible to be exempted from the energy and carbon dioxide tax with a level of just under €120 EUR/tonne of fuel. Only biofuels that abide to the Swedish legislation and that fulfil the RED sustainability criteria, may be taken into account for the fulfilment of European targets or be entitled to state aid. Sweden introduced a biofuels mandate in 2014 and managed to achieve a large uptake of (conventional) biofuels[23] with a tax support level of 120 EUR/tonne.[24] The Swedish example shows that it is possible for a tax incentive to successfully drive the biofuels market. Outside the EU the 'VEETC' fiscal incentive was in place in the US from 2005 to 2011.[25]

While national EU Member States can introduce tax incentives it is not possible for them to completely abolish the fuel tax for advanced biofuels because the EU sets minimum energy tax levels. The European Commission published a legislative proposal in 2011 to revise the Energy Tax Directive[26] with the aim to lower the minimum tax level for petrol (and ethanol) and increase the minimum tax level for diesel (and biodiesel), to make the tax level partly dependent on $CO_2$-intensity of the fuel and to exempt biofuels from the proposed $CO_2$-component in the tax. The proposal did not make it into final legislation as taxation is a sensitive issue with unanimity required in the European Council. The differences between current excise duty levels and the EU minimum required levels are however large enough to allow for impactful tax reductions. For unleaded petrol the minimum excise

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[21] The UK had a tax rebate of 20 pence per litre of biofuel in place in 2005-2008. The rebate was dropped because the incentive proved to be too small to deliver the expected quantity of biofuels, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266390/rtfo-consultation-document.pdf

[22] Lag 1776 was introduced in 1994. In Sweden, energy and carbon dioxide taxes are levied on the supply, import and production of fossil fuels with tax exemptions for biofuels.

[23] In 2012 Sweden consumed 0.6Mtoe of biofuels, http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro216_en.pdf

[24] http://www.lsta.lt/files/events/2014-05-12_13_AEBIOM%20konf/2014-05-13_pranesimai/Parallel_1/04_Kjell-Andersson-AEBIOM-2014.pdf

[25] Under the VEETC, registered ethanol blenders were eligible for a tax incentive in the amount of $0.45 per gallon of pure ethanol (minimum 190 proof) blended with gasoline. The VEETC ran from 2005 to 2011 and cost approximately $5 to $6 billion in tax revenue reduction annually ($5.4 in 2010 and $5.7 billion in 2011 according to the US Government Accountability Office). The total amount of tax reduction for this program amounted to approximately $30.5 billion over its lifetime.

[26] http://ec.europa.eu/taxation_customs/resources/documents/taxation/com_2011_169_en.pdf

duty tax is €359 per tonne, for diesel €330 per tonne[27]. While in some Member States, such as Romania, Bulgaria the Baltic states and Spain the actual excise duty tax level barely exceeds these minimum levels, in others, such as France, Germany and the UK, the actual tax levels far exceed the minimum levels, creating the theoretical space for meaningful incentives.

Offtake risk

A tax incentive, being it in the form of a excise duty reduction or a waiver from a carbon tax on fossil fuels can be a good way to support biofuels, as the Swedish example shows. A specific arrangement could be made to differentiate advanced biofuels from conventional biofuels to ensure that the support has an impact on the uptake of advanced biofuels. The level of support determines whether the measure can have the impact to really reduce the offtake risk in the sense that the cost difference between advanced biofuels and fossil fuels is sufficiently reduced or even reduced to zero.

In Chapter 2 we estimate that cellulosic ethanol can be produced for €750 per tonne. This is €45 more than the average current EU petrol price as provided in the Appendix. This does not mean that a tax incentive of €45 per tonne will be sufficient as margins for the biofuel producer and fuel supplier have to be factored in as well. In Sweden the tax incentive has a value of around €120 per tonne. This level was sufficient for conventional biofuels during a time when the tax exemption was the main Swedish policy measure in place. Based on this, a tax incentive as a stand-alone driver of advanced biofuels would probably require a higher level of support depending on the type of advanced biofuel.

How expensive would such a measure be if a tax reduction of €120 per tonne would be given for advanced biofuels across the EU? The total EU fuel pool is expected to stand at 12,294 Petajoule (PJ) in 2020. If it is assumed that a policy incentive should achieve 0.5% advanced biofuels, this means that 61.5 PJ of advanced biofuels is required, or 2.9 billion litres of cellulosic ethanol or 1.9 billion litres of advanced renewable diesel or a combination of both. If supplied fully with cellulosic ethanol, the total fiscal cost of the policy would be around 348 million EUR/year for the EU as a whole for a relatively small quantity of advanced biofuels. A tax break can help to get positive investment decisions for early commercialisation of cellulosic biofuels in addition to a specific mandate or specific carbon intensity reduction target for advanced cellulosic biofuels. In such way the tax break can be capped in time and budget and still help to support investment decisions.

Regulatory risk

All policy measures can be changed and regulatory certainty will never be complete. Fiscal support has a direct impact on government budgets and therefore relatively dependent on the financial health of the government budget. Compared to mandates, fiscal incentives are more vulnerable for regulatory changes since they are paid from the government budget rather than by consumers at the fuel pump. A fiscal mandate could be made more 'future proof' by tendering fiscal allowances. This essentially caps government expenditures and ensures a certain quantity of biofuels being supplied to the market. It also helps if the tax incentive is capped in time and budget, which can be the case if

[27] http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/rates/index_en.htm

the aim of the incentive is not to bridge the entire price gap between advanced biofuels with conventional biofuels or fossil fuels but if the aim is to give some degree of support in addition to other measures such as a mandate.

**Tendering**

France provides an example of how tendering can work. France also has tax measures:

- Petroleum tax (TICPE)[28] tax reduction will terminate in 2016
- Pollution tax (TGAP)[29] is the dominant incentive. Fuel suppliers that meet the mandate don't pay this tax while fuel suppliers who fail to meet their mandate must pay the full tax and double counting is related to this tax.

The TICPE tax break expenditure is capped and auction is organised each year to divide the budget over economic operators who need to ensure that a certain volume of biofuels will be delivered at a certain fixed price during a three-year period. Biofuel producers are ensured a guaranteed offtake during this period against an attractive price that includes a fiscal benefit. Tendering will be abolished in 2016 but could form a template of what a policy measure specifically aimed to support advanced biofuels could look like. For advanced biofuels, a fixed offtake period of three years would not be sufficiently long, an initial period of five years after which producers can participate in a new tendering round could be a more future proof policy measure compared to an 'open end' fiscal measure because the tendering ensures that governments can control the cost of fiscal support. In France often French companies benefitted from the auction which is logical from the perspective that there is French tax-payers money involved. The risk that auctioning takes a national perspective bears the risk that not the cheapest producers are being selected to receive fiscal support. From the perspective of fostering innovation and cost reductions, the auctioning should focus on producers offering the lowest production costs.

<u>Financing risk</u>

As the measure is not future proof, the impact on offtake risk reduction is small and a decrease in financing risk is not foreseen. A kind of tendering approach might reduce the finance risk.

<u>Feedstock risk</u>

As discussed under the energy mandate in section 4.1, the question whether a feedstock risk will occur or not depends on the chosen production location and on whether residual biomass or energy crops are used. While it is not straightforward that a feedstock risk will indeed occur, the introduction of a policy measure that increases advanced biofuel production increases the feedstock risk for residual biomass and only in those areas where feedstock supply is short and might trigger improved crop economics for dedicated energy crops.

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[28] TICPE (Taxe intérieure de consommation sur les produits énergétiques, previously TIPP). Biodiesel receives a reduction of 4.5 Eur/hl in 2014 and 3 Eur/hl in 2015 (was 8 Eur/hl in 2013). Bioethanol receives 8,25 €/hl in 2014 and 7 €/hl in 2015 (was 14€/hl in 2013). Will be eliminated per 2016.

[29] TGAP (Taxe Générale sur les Activités Polluantes, tax on polluting activities, including fuels) levied by the customs authorities, will remain in place.

The table below summarises the assessment provided above for **fiscal support measures**.

**Table 5 - Impact of fiscal incentive in reducing investors' risks**

| Criteria | Assessment |
|---|---|
| Reduction of offtake risk | To some degree, especially as a supporting measure to other measures |
| Reduction of regulatory risk | Fiscal support is paid by the government and therefore more prone to being abolished since it will be a costly measure, tendering might give some certainty |
| Reduction of financing risk | Decrease in financing risk is not foreseen, maybe when tendering is introduced |
| Reduction of feedstock risk | Increased risk when residual biomass is used in areas with limited feedstock availability, less or little risk for energy crops or in areas with abundant supply |

**Green: risk can be reduced, yellow: risk can be partly reduced or unclear whether risk will occur, red: unlikely that risk can be reduced**

## 4.4 Investment support measures

Governments can provide direct financial support to advanced biofuel projects, either at national or at EU level. Several options for investment support exist at EU level:

1. The NER 300[30] programme offered €2.1bn support to nearly fourty renewable energy projects including several investment subsidies for 1st of a kind commercial plants, including a grant of €199mln for the Woodspirit project to produce methanol from woody biomass in the Netherlands and a grant of €170mln to UPM to invest in a Fischer-Tropsch renewable diesel facility using woody biomass near Strasbourg in France;
2. The Horizon 2020[31] programme provided funding for research and innovation and demonstration stage projects. In 2014 for example, €94 mln was awarded for research into advanced biofuel technologies.
3. The European Industrial Bioenergy Initiative (EIBI) [32] which offers funding for demo-scale and first in kind commercial plants (collaborates with BESTF2);

[30] http://ec.europa.eu/clima/policies/lowcarbon/ner300/index_en.htm
[31] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/1143-lce-12-2015.html
[32] https://setis.ec.europa.eu/system/files/Bioenergy%20EII%202013-2017%20IP.pdf

The most prominent vehicle for investment support by EU Member States level support is the BESTF2[33] programme, funded by six EU Member States plus Switzerland for demonstration stage projects. Also, the UK recently held an advanced biofuels competition which supports innovative commercial projects in the UK.[34]

Offtake risk

Investment support measures can help to get projects built but do not help to create demand. Therefore, investment support measures should be part of a wider regulatory package including measures to reduce offtake risks.

Regulatory risk

Investment support is future proof for individual investors in the sense that once investment support is granted and paid-out, the support is certain for the investor.

Financing risk

As the government provides some of the necessary funding, financing risks for private investors are reduced. Investment support reduces the amount of capital required for a project and therefore reduces financing risks.

Feedstock risk

See under previous policy measures

The table below summarises the assessment provided above for **investment support measures.**

**Table 6 - Impact of investment support in reducing investors' risks**

| Criteria | Assessment |
|---|---|
| Reduction of offtake risk | Investment support alone does not reduce offtake risk |
| Reduction of regulatory risk | Investment support is guaranteed and "future proof" |
| Reduction of financing risk | Decrease in risk corresponding to the government funding support |
| Reduction of feedstock risk | Increased risk when residual biomass is used in areas with limited feedstock availability, less or little risk for energy crops or in areas with abundant supply |

**Green: risk can be reduced, yellow: risk can be partly reduced or unclear whether risk will occur, red: unlikely that risk can be reduced**

## 4.5 Conclusions

In this chapter, four possible policy measures are assessed to stimulate investments in advanced biofuel production installations: a specific mandate for advanced biofuels, a carbon intensity reduction target, a fiscal incentive and investment support. For each of these measures their impact in reducing

[33] http://eranetbestf.net/two/

[34] https://www.gov.uk/government/speeches/advanced-biofuels-demonstration-competition

the offtake risk, regulatory risk, financing risk and feedstock risk were assessed. The table below summarises the extent to which the assessment policy incentives reduce risks for investors.

**Table 7 - Impact of assessed measures in reducing investors' risks**

| Criteria | Mandate | Carbon saving target | Fiscal support | Investment support |
|---|---|---|---|---|
| Reduction of offtake risk | Green | Green | Green | Red |
| Reduction of regulatory risk | Yellow | Yellow | Red | Green |
| Reduction of financing risk | Yellow | Yellow | Red | Green |
| Reduction of feedstock risk | Yellow | Yellow | Yellow | Yellow |

**Green: risk can be reduced, yellow: risk can be partly reduced or unclear whether risk will occur, red: unlikely that risk can be reduced**

Feedstock risk will often not occur. In situation where it occurs, when a plant using agricultural residues in an area where the material is already widely used by other sectors. The most important risks to be mitigated from the perspective of investors are the offtake and regulatory risks. Measures can reduce the offtake risk either by enabling advanced biofuels to compete with conventional biofuels in the same market or by fencing off a market for advanced biofuels, by measures that decrease advanced biofuel production costs or by measures that increase revenues. A specific, high enough mandate for advanced biofuels, a specific high enough carbon saving target and a sufficiently high level of fiscal support can all reduce the offtake risk whereas from the perspective of an investor only investment support offers certainty from a regulatory perspective. This makes investment support an interesting accompanying measure to one of the other three.

The degree to which regulatory risk will materialise depends on the level of public support for advanced biofuels, if active support is widespread than either a mandate, carbon target or fiscal support can reduce the offtake risk in a satisfactory manner. However, probably a specific mandate and specific carbon saving target offer more certainty than a fiscal measure because the latter is paid for from the government budget which makes it a potential target for savings in times of austerity, whereas the first two are paid for by consumers at the pump. Some increased regulatory certainty can be achieved by tendering fiscal support, which essentially prevents the measure to become an open ended bill for the finance minister. Fiscal support can also play a helpful role not as stand-alone but as a supporting measure in the early commercialisation of advanced biofuels, to offer limited support for a fixed number of years in an advanced biofuel market that is primarily driven by a specific mandate or carbon target.

Either a specific mandate, a carbon target or fiscal support can deliver an increased deployment of advanced biofuels, ideally accompanied by a form of investment support to reduce high capital costs for first and second of a kind investments. Whether such a combination of policy measures or 'policy stack' can really mitigate risks depends on how measures are designed. A mandate, carbon target or fiscal support should be fixed for at least eight to ten years to allow investors to return their investment. Ideally, this period would be longer to enable investors a longer period to return their investment, but regulatory certainty for longer than ten years is probably not very realistic. Mandates should have a high enough buy-out price, should be specific for advanced biofuels and should be embedded in the right storyline in order to receive sufficient levels of societal support. A carbon saving target must allocate a specific part of the target for advanced biofuels in order to effectively drive investments in advanced biofuels. This means that dedicated, longer term policy measures will be required to really advance the market for advanced biofuels in Europe.

# Appendix: Cost modelling assumptions

This appendix gives the assumptions used for the purpose to estimate production costs of NOAK production installations for three selected biofuel pathways.

| Parameter | Unit | Value | Data source |
|---|---|---|---|
| **Plant data** | | | |
| Plant lifetime | yrs | 20 | Estimate |
| Start-up capacity | % | 50 | Estimate |
| | | | |
| **Financial data** | | | |
| Own capital | % | 10 | Passmore Group estimate |
| Debt share | % | 50 | Passmore Group estimate |
| Equity share | % | 30 | Passmore Group estimate |
| Grant share | % | 10 | Passmore Group estimate |
| Interest rate on Debt | % | 14 (FOAK) 12 (NOAK) | Passmore Group estimate |
| Interest rate on Equity | % | 16 (FOAK) 10 (NOAK) | Passmore Group estimate |
| Interest rate on Own capital | % | 0 | Passmore Group estimate |
| Repayment period | yrs | 15 | Passmore Group estimate |
| Inflation | % | 2 | Estimate (applied to all relevant parameters) |
| | | | |
| **Feedstock costs** | | | |
| Agricultural residues | EUR/t wet | 65 | Interviews, literature |
| Forestry residues | EUR/t wet | 50 | Interviews, literature |
| | | | |
| **Utility prices** | | | |
| Electricity – Export to grid | EUR/MWh | 40 | EU Energy Statistics (EU-28 2014 estimate)<br>No Feed-In-Tariff assumed |
| Electricity – Purchase | EUR/MWh | 65 | Eurostat (EU-28 2014 estimate) |
| Natural gas | EUR/MWh | 33 | Eurostat (EU-28 2014 average) |
| Steam (Low pressure) - Export | EUR/t | 20 | Industry source |
| | | | |
| **Fuel prices** | | | |
| Diesel | EUR/t | 669 | EU Energy Statistics (EU-28 2015 YTD average) |
| Gasolene | EUR/t | 705 | EU Energy Statistics (EU-28 |

| Parameter | Unit | Value | Data source |
|---|---|---|---|
| | | | 2015 YTD average) |
| Biodiesel | EUR/t | 800 | Biofuels International (SCB - Commodity Brokers Global Biofuels Prices) |
| Biogasolene | EUR/t | 750 | Biofuels International (SCB - Commodity Brokers Global Biofuels Prices) |
| Cellulosic ethanol | EUR/t | 761.25 | Biogasolene plus 25% of theoretical full double counting premium |
| Hydrotreated Pyrolysis oil | EUR/t | 832.75 | Biodiesel plus 25% of theoretical full double counting premium |
| Fischer-Tropsch renewable diesel | EUR/t | 832.75 | Biodiesel plus 25% of theoretical full double counting premium |

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